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THE WATERPROOFING OF STRUCTURES

With Special Reference to Sub-level Construction, the Envelope Method and the use of "Tunaloid"

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WITH SPECIAL REFERENCE
TO SUBLEVEL CONSTRUCTION,
THE ENVELOPE METHOD
AND THE APPLICATION OF
"TUNALOID"

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The Waterproofing of Structures

A PRIMARY function of practically every type of structure is to prevent the entrance of moisture. As a rule, those which extend above the surface have merely to shed the rain. The materials of construction themselves, roofing in its various forms, paint or plaster, serve effectually to meet the requirements. The surfaces are readily accessible for repairs, and except where water pockets are formed there is comparatively little difficulty in making such a structure moisture proof. An exception exists in the case of such structures as steel and reinforced concrete bridges exposed to the weather and subject to vibration, where extremes of temperature have a serious effect in causing expansion and contraction, and where water may stand for considerable periods.

But below surface level the conditions are changed, and the difficulties vastly increased. In its natural state earth is always moist. It is the recipient of all the rain that falls. In the case of open sand and gravel, it sinks rapidly to lower levels, which in clayey soils or in ledge formations remain pocketed for long periods relatively near the surface.

In the sublevel structure like the ordinary house cellar, with its bottom seldom more than eight or ten feet below the surface, there is seldom much difficulty in preventing the entrance of water. The pressure due to its head is comparatively slight and well laid walls, or concrete foundations, with proper subdrainage conducted to a point of free discharge usually insure freedom from all annoyance.

But when an excavation is made in springy ground or its bottom is below the level of nearby water in lake, river, or sea, percolation inevitably results. The open space furnishes a ready receptacle toward which the water naturally flows under

this pressure due to its depth. There being no lower level to which it may be drained it becomes imperative that the excavated area, surrounded as it may be by such a body of water, should be completely enveloped in an absolutely impervious shield. Such a shield is not provided by the ordinary foundation.

With the recent rapid advance in building methods, and the growing values of sublevel spaces in large communities, the problem of securing absolute freedom from moisture within such structures has become serious and increasingly difficult of solution. At depths of 30 to 40 feet water pressures may rise to over a ton per square foot of surface. Hydrostatic pressures at different depths are given in the accompanying table.

HYDROSTATIC PRESSURES.

Hydrostatic Head Feet	Pressure Per Square Inch Lbs.	Pressure Per Square Foot Lbs.	Hydrostatic Head Feet	Pressure Per Square Inch Lbs.	Pressure Per Square Foot Lbs.
0.5	0.21	31.2	12.0	5.21	750.0
1.0	0.43	62.5	15.0	6.51	937.5
2.0	0.86	125.0	20.0	8.68	1250.0
3.0	1.30	187.5	25.0	10.85	1562.5
4.0	1.73	250.0	30.0	13.02	1875.0
5.0	2.17	312.5	40.0	17.36	2500.0
6.0	2.60	375.0	60.0	26.04	3750.0
8.0	3.47	500.0	80.0	34.72	5000.0
10.0	4.34	625.0	100.0	43.40	6250.0

So far as the stability of the structure itself is concerned such pressures are easily resisted by the thickness of the walls necessary to support the superstructure and withstand the lateral pressure of the earth. In the tunnel or subway such resistances may be provided with engineering certainty and usually without complicated design. In a word, deflection and destruction may be readily prevented.

But to prevent the entrance of water is a far more difficult problem. In fact the successful construction of a substructure in any way exposed to external water ultimately depends upon the perfection of the waterproofing method employed. Once built, its exterior is practically inaccessible. Hence, an ounce of prevention is most emphatically worth more than a pound of cure.

All structural materials used for foundations or similar purposes are of necessity hard, rigid and inelastic. Though more or less impervious through their substance, they usually present opportunity for passage of water at their joints, or through cracks which because of their inelastic nature are almost certain to develope.

Brick, which is exceptionally porous, is seldom encountered in large structures where the waterproofing problem assumes distinct magnitude. Broken or cut stone which formerly prevailed as a substructural material, presents in the completed wall no end of possibilities for inward leakage at the multitudinous joints. But concrete has now become so universal as a foundation building material that all others are of secondary importance.

If concrete were a homogeneous material, always of the same composition and characteristics thoroughout, the question of its permeability might be readily and conclusively settled. But composed as it is of various aggregates,—cement, sand and gravel or broken stone,—each differing greatly in its individual quality, mixed in a wide range of proportions, and with varying degrees of thoroughness, concrete becomes merely a generic name. The laboratory sample can never be more than an average of the material in the completed structure, which in itself may vary widely in different portions.

While it may be possible to render a small mass of concrete entirely impervious to water it is still an open question whether a multitude of such small masses may be so united that the entire body will always be impermeable.

It is a condition and not a theory with which the engineer is confronted. To secure impermeability, every particle of sand must be coated with cement and every particle of stone must be so surrounded with this cement and sand that the stones and the sand grains do not come in actual contact but are always separated by films of cement which completely fill all voids. Such perfection is entirely dependent upon the skill with which the ingredients are mixed and placed in position and this in turn determines the cost of the structure.

It has been generally considered that the cheapest labor was sufficient for the mixing of concrete and that to reduce its permeability it was only necessary to use plenty of cement. But with such unskilled labor, no matter what the richness of the concrete, there is always the probability of improper setting and the imperfect bonding of portions of the work laid at separate intervals.

Although the quality of the work may obviously be improved by the employment of higher paid men, there still remains the possibility of imperfection. It is this possibility always present in such construction which, aside from other causes, renders imperative the employment of independent means for absolutely insuring the impermeability of the entire structure.

As a rule experiments upon permeability give somewhat uncertain results, and it is not unusual to find blocks of the same concrete which although treated in an identical manner, permit very different quantities of water to filter through them. In a general way it has been determined that the permeability of concrete diminishes as the proportion of cement is increased. When the composition itself is varied a wide variation in watertightness is usually the result.

What is true of composition is likewise true of thickness. Because of variations in proportions and methods of laying it is impossible to specify definite thicknesses of concrete to prevent percolation under different heads of water. Rain water under a head of two or three inches has been known to percolate through a four foot wall of excellent concrete and dry consist-

ency, while a three inch wall under four feet head of water has proven perfectly tight. These facts only emphasize the uncertainties prevailing in so called water-tight concrete construction.

Continuous tests have shown that ordinary seepage through concrete usually decreases with time. This has been attributed to the gradual stopping of the pores by the carbonates of lime which result from the attack of the cement by lime-carrying water passing through it and its subsequent exposure to the atmosphere. These efflorescenses tend to solidify the mortar and form an outer coating, and are the material cause of the gradual decrease in percolation of water. It is but natural therefore that hydrate of lime should be suggested as an ingredient of the concrete to be introduced at the time of mixing. This like many other materials, such as sulphate of alumina, soap, alum, or metallic stearates has been made the basis of compounds designed to be incorporated with the concrete for making it water-tight. These act in various ways, and in the case of many so called waterproof compounds of unspecified composition put together without regard to chemical principles, the effect upon the endurance of the concrete is absolutely unknown. In some cases they have been found to contain a large proportion of inert substances which interfere with the nominal setting of the concrete and materially decrease its strength while exerting a negative influence upon its permeability.

But aside from these facts success in the use of an otherwise proper ingredient always depends upon the thoroughness with which it is incorporated into the concrete. Even distribution throughout the mass is absolutely necessary. Here again is the ever present possibility of imperfect work, which leaves actual service as the only proof that it has been done properly. To many this risk appears too great to be undertaken and as a consequence, a waterproofing method is adapted which permits of inspection during its application.

But after all is said and done the absolute impermeability of the material of the structure may count for little in its ultimate

ability to prevent the admission of water from the surrounding soil. Being of necessity an inelastic material, ruptures in the form of minute, hardly perceptible cracks or more clearly defined crevices are always liable to occur under strains induced by temperature changes, settlement, warping, etc. The elasticity of concrete, such as it is, varies with its composition and the size of the stone. But in no sense can concrete be considered an elastic material. Its co-efficient of expansion per degree Fahrenheit ranges from .000005 to .000008 according to the mixture. The expansion averages about the same as for iron or steel which therefore proves a suitable material for reinforcement. The actual variation in dimensions is better realized by considering 100 feet in length of concrete and a temperature change of 100 degrees F.; the change in length is then three quarters of an inch. The same increase in temperature will increase by .40 cubic foot a 10 foot cube of concrete.

Although an ordinary structure 50 or 60 feet in any dimensions can, with careful attention to all details, be constructed to take up temperature stresses without the introduction of reinforcement, it is still always subject to possible minute rupture or to such imperfections in the bonding or joining of successive batches of concrete as will permit of the passage of water. It is always possible that channels may be established through which the water may percolate.

In larger structures, iron or steel reinforcement will insure general provision for expansion and contraction through cracks confined by the construction to certain definite places. But imperfections are still possible in the balance of the work. The cracks may be treated as joints to be made water-tight by special means, with the possibility, however, of ultimate leakage if the material employed is directly and rigidly attached to the concrete on either side and obliged to move with it.

Manifestly then, while concrete may of itself in the case of laboratory specimens and small batches mixed with special care prove practically impervious, in large masses mixed perchance

by unskilled labor there must always be an element of doubt which can only be removed by the proof of water-tightness in actual service. Such tightness is not to be measured by the absence of dripping water but by absolute freedom from the least appearance or feeling of moisture upon the inner surface. Though such a condition may prevail in a structure shortly after its completion, the stresses which always exist may eventually find relief long after in the form of local ruptures. In a word there is always risk of leakage.

The method whereby it is undertaken to render concrete impervious by the introduction of an ingredient is manifestly so simple that had it proven as economical, practical and effective for substructural as for superstructural work there would be no reason for the consideration of any other methods. But the fact that it is not generally employed and that other methods prevail is manifestly the best evidence of their superiority.

Such are those concerned with some external application to the surface or the enveloping of the entire structure in a practically independent pliable waterproof envelope or shield.

Surface coatings are as old as concrete itself. For centuries neat cement has been used in the form of a wash or a trowelled grout. Under the conditions previously prevailing, where great depth of substructure did not exist and absolute impermeability was not necessary, such simple means have appeared sufficient. In similar manner asphalt or coal tar pitch has been applied hot as protection against the passage of water. For years Sylvester's solution of alum and soap has been applied in many coats with varying success.

Concrete surfaces have been impregnated with paraffine, paint in a hundred forms has been used, enamels and the like have been brought to notice. In many cases they have proved practical and efficient for the waterproofing of structures above the surface but absolutely useless for those below. It is eminently logical that any protection whether applied directly to the surface or merely enveloping it should be upon the water side and that it should serve to prevent contact of water with

that surface. Once admitted to contact with the concrete the water will search out and follow every channel, no matter how minute, that leads through its substance. In the case of reinforced concrete it is urgently necessary that the steel should be absolutely protected from moisture. This certainly cannot be done unless the entire structure is completely and effectively enveloped in a waterproof shield. But under the ordinary conditions of construction the application of any coating direct to the outside of a completed wall of a substructure entails the excavation of an external area sufficient for working space. The cost of such excavation aside from other considerations is alone sufficient reason for considering such a method impracticable, particularly at any great depth. Where the surface is exposed above ground level during construction it is of course easy to apply any form of waterproofing.

It is but natural that because of the ease of application coatings should be tried upon the inner rather than the outer surfaces of structures below ground level. But this always leaves water free to exert its pressure to push off the coating rather than bind it faster to the surface as would be the case if it was applied upon the outside. It is this fact that has rendered so many forms of inside coating absolutely useless.

The only possibility of opposing a reasonably effective stop to the water by an inside application lies in making it of ample thickness and bonding it effectually to the existing concrete. Waterproofing cement in various forms has been tried under these conditions. In one of the most successful forms it combines with the good qualities of a first class Portland Cement the power of repelling water. It is usually applied in a coating about $\frac{5}{8}$ of an inch thick but requires a special sand for its mixing and especially skilled labor in its manipulation.

Its success depends primarily upon its adherence to the wall, but being deficient in elasticity the shrinkage cracks on reinforced concrete are sufficiently large to fracture the coating and render it of questionable value.

From this somewhat critical discussion of waterproofing methods it is clearly manifest that the integrity of any material or method lies not in itself but in the concrete or other structural material with which it is incorporated or to which it is applied. Variety in material and mixtures as well as lack of skill in the work always leave its character in doubt. So long as the thoroughly made wall or floor remains intact there is a possibility that some of the better methods of waterproofing already mentioned may prove successful, but the moment the slightest fracture occurs trouble begins if water be present.

Theoretically a substructure may be made watertight by such means, but practically there always exists the possibility of imperfection and failure. In the present state of the building art and doubtless for years to come this possibility cannot be overlooked and definite steps must be taken to insure against the effect of its occurrence. Such insurance can take only one practical form, namely the provision of an exterior pliable waterproof envelope or shield composed of materials unaffected by water, or other matter in the soil, durable under all conditions and free from the influence of movement on the part of the structure itself.

A shield or envelope to fulfil these conditions must consist of more than a mere coating applied to the outer surface of the structural material. No matter how thick an application of asphalt, cement or mastic compound of both materials may be, its resistance to rupture is by no means increased by such thickness. So long as it maintains a bond with the wall to which it is applied, and this is always necessary, it must expand or contract, twist or settle with that wall. Seldom does such a coating have the same elasticity or the same coefficient of expansion as the structure to which it is applied. Hence it may crack even when the wall does not and is practically certain to when it does. In a word, such a surface coating is in no sense a separate envelope but an integral part of the wall, and hence fails to fulfil the first requirement of the envelope method, i. e. opportunity for independent movement.

The true envelope or shield must be free to move or remain stationary with practical independence of the structure, it must be a shell or shield which entirely, or so far as may be necessary, surrounds the structure and prevents all water from coming in contact with it.

In its most practical and economical form such an envelope is composed of a series of layers or plies of a suitable fabric cemented together with a waterproofing compound. Above all the fabric must of itself be waterproof so that each individual layer may serve as an independent barrier to the passage of water, while the intermediate coatings of cementing compound must individually supplement this waterproofing quality and collectively bind the series of plies into a pliable sheet of substantial thickness. The particular attributes of a suitable felt and a satisfactory cement are hereinafter discussed.

As with all materials of this character their successful use depends largely upon the care with which they are applied. A primary requirement with all waterproofing laid in layers of fabric is that the edges shall overlap so that as sheet after sheet is laid side by side these laps shall be uniform and the number of thicknesses be the same in all parts. It is also necessary that these sheets as they are successively laid shall be securely cemented to each other, that there shall be no air pockets causing separation of the sheets and no uncoated surfaces, the spaces between which might furnish channels for the passage of water.

Beyond such general requirements for satisfactory work no set specifications can be established. Each class of work requires its own particular treatment as regards material and method of application. The general methods employed with various types of structures may however be briefly considered here, although discussed at length hereafter.

The development of the steel bridge with gravel or macadam filled road way for vehicles or similar bed for railroad tracks has led to a demand for special protection for the steel surfaces beneath the roadway or track. Hidden as they are these surfaces must be so thoroughly protected from moisture that

deterioration will be almost impossible. The futility of relying on coatings or coverings of cement, concrete or a more or less elastic mastic has been shown in many cases, for the excessive expansion and contraction resulting from a range of perhaps over a hundred degrees in temperature have been the cause of almost inevitable rupture. But the difficulty has been successfully overcome by the use of waterproof felt in combination with a cementing compound. By similar means, reinforced concrete bridges have been rendered impervious to the passage of water from the road bed while deterioration and positive danger have been shown to result in the case of structures not so protected.

In "cut and cover" construction where the surface to be waterproofed is exposed during the building process and subsequently covered as in the case of some great tunnel undertaking the best opportunity is presented for the employment of the envelope method. Here the felt and its intermediate coatings are readily applied to the exterior surface; inspection of the work is simple and reasonably good workmanship is insured.

But where excavation is necessary for the building of the structure which is to be waterproofed the problem becomes more involved. Here the manifold shield must be formed in advance of the construction which it is to envelop. This is usually accomplished by first building against the wall of the excavation a light wall of brick or similar material to which the fabric forming the shield may be applied. When this has been done in a sufficient number of layers in connection with the cementing compound the wall of the structure itself is built. In this manner the envelope is most logically constructed as an enclosure for the structure.

In driven tunnels entirely beneath the surface the waterproofing felt is usually applied to the smoothed walls formed in the process of excavation. Within this core or envelope the finished walls are then built.

Manifestly each type of structure requires its special treatment. Practical illustrations are given in succeeding pages.

Certain reasonable risks may be run and experiments tried in structures where correction, repairs or changes may subsequently be made without danger or difficulty. But in the case of waterproofing it is imperative that no chances be taken; for the risk is too great—to make good a bad job may entail an expense ten to twenty times its original first cost. Hence only the most suitable method and the very best of materials should ever be employed. The superior advantages of the envelope method having been considered it is but proper that attention should next be given to the necessary qualities of a waterproofing felt.

Time was when so called tar paper was the best and in fact practically the only material available for use in the then undeveloped practice of waterproofing by the envelope method. Before the general advent of wood pulp even the paper used for building purposes was of good quality with distinct fibre and reasonable strength. The coal tar used for saturation was likewise of far higher grade than is employed to-day. It is not strange then that work executed years ago with such relatively good materials should, where not exposed to unduly destructive agencies, be now and then found to be in good condition. It is this very fact combined with lack of knowledge of progress in the science of waterproofing that still leads some to employ the present day materials which pass under the same name.

But tar paper or coal tar felt is to-day ordinarily a cheap material of little strength and less endurance under the searching requirements of modern waterproofing construction. The paper is usually of short fibre, hard and brittle. The coal tar used as a saturant has been refined to such a point in order to extract the various products which are more valuable for other purposes, that the coal tar left and used for saturation is practically nothing but a residuum of little value for any purpose.

The gradual reduction in quality of such material combined with the increasing demand for a fabric eminently suited to modern requirements has led to the development of various fabrics almost universally called "waterproof" although pos-

sessed of that quality in various degrees. An intermediate stage in this development is marked by the attempt to use a woven fabric like burlap or similar cheap material as a carrier or absorbent for a certain amount of waterproofing compound and as a support or conveyer for applied coatings of cementing compound.

Fundamentally the completely vegetable character of such material is objectionable for it is possessed of little durability when exposed to underground conditions. The fact that it is woven still further contributes to its unworthiness; for unlike a uniform fabric similar to felt or even paper its body consists of alternate material and interstices. Upon the compound employed for saturation and coating therefore falls the burden of completely closing these spaces as well as of rendering impervious the actual material of which the fabric is made. What is more, the crossing of the fibres in the warp and woof results in an arrangement which entails a readjustment of relations the moment the fabric is stretched or twisted; a consequent change in shape of the individual interstices takes place. The result is obvious,—water-tightness cannot be maintained except at excessive cost.

On the other hand a material having the characteristics of a felt or paper with the fibres matted together is of the same texture throughout; if made of suitable materials it is always amply pliable. The minute individual fibres, if properly saturated, work almost infinitesimally upon each other when the material is stretched. The saturant itself fills all pores with the result that the felt retains its waterproof character even when subjected to great strain and distortion.

Waterproofness, pliability and durability are obviously the prime essentials in such a felt. As in all materials the quality of the finished product depends upon the individual qualities of its ingredients. The exacting demands made upon a waterproofing felt and its relatively small cost as compared with the damage which may result from possible inferiority makes it imperative that only the very highest grade of materials should

be used in its manufacture. But the quality of the ingredients, even though of the best, does not alone determine the real value and efficiency of the product when used for a specific purpose. Character and suitability in view of the conditions are of equal importance.

Take the case of wool for instance as one of the substances incorporated in the felt. Because of its superiority to other available materials, as an absorbent of the saturating compound, wool is invaluable in a waterproofing felt. Its percentage therefore determines the possible degree of saturation. A well made felt is generally most effective as a waterproofing material when it contains the amount of suitable saturant which can be held by an amount of wool equivalent to from a minimum of 20 to a maximum of about 30 per cent. of the weight of the unsaturated fabric. A lesser amount would leave the felt inadequately waterproofed while a greater amount would so increase the relative amount of saturating compound as to decrease the strength. Hence it is evident that in a reputable fabric even though known as a "wool felt" the proportion of wool should average about 25 per cent.

The balance should be made up of such material as will best serve in combination with the wool and the saturant to form the most pliable, durable and waterproof fabric. The saturating and coating compounds should be of a character capable of remaining plastic after long heating at a temperature of at least 250 degrees and the surface of the felt should not crack when bent double at ordinary temperature.

The saturant employed for such a felt must not only serve specifically as insulation against moisture, but it must remain unaffected by continued contact with water or dampness, even at high or low temperatures, it must not deteriorate with age, and must be capable of resisting the chemical action of all ordinary agents which may be found in ground waters, escaping sewerage and the like, and permit the felt to remain permanently pliable. In its best form such a compound should be a combination of gums and mineral non-volatile oils insoluble

in water, and should retain some of the properties formerly found in coal tar but which are now customarily extracted from it before it is used for saturating the cheaper felts. All injurious chemicals should be eliminated.

Many of the so-called waterproofing felts are saturated and coated only with common asphalts or tar, which will dry out and become brittle, and render the felt worthless. Waterproofing is of too much importance to risk the use of such methods.

A suitable felt should be capable of easy application and as a matter of importance should have a natural affinity for any of the reliable mineral pitches, distillates of straight asphalt or straight coal tar, which may be employed for cementing the sheets of felt together, in the process of applying the work. Only in this way may perfect bonding be assured. In the process of saturating it is customary to also leave upon the felt a distinct waterproof coat. This must be thoroughly pliable, not subject to cracking at low temperatures or liable to become too plastic and adhesive at high temperatures. Under normal conditions it must of necessity be somewhat "tacky." As a result when felt which is coated upon both sides is rolled in the usual manner for shipment, it is practically impossible to prevent the adhesion of the adjacent coated surfaces except by the expensive method of separating them by the introduction of paper, or by reducing the adhesiveness of one of the surfaces by coating it with some substance such as talc or ground wood pulp. But when a sufficient amount is applied to prevent adhesion in the roll the affinity of this coated surface for the hot pitch employed in laying the felt in position is very much lessened.

This practical objection is removed when only one side of the felt is coated. Then only the minutest amount of talc or its equivalent is required to keep the surfaces from adhering in the roll. A quarter of a pound per one hundred square feet is usually sufficient, in fact the amount is so slight as to be barely perceptible.

But what is more important, it has been conclusively demonstrated by experience that better adhesion on the work is secured between the different plies when only one side is coated. The hot pitch which in the process of laying is applied to the cement or mortar construction or to the coated side of the felt is found to adhere in its rapidly cooling condition much more readily to the uncoated surface of a piece of felt pressed against it.

The explanation appears evident. The compound which is almost universally applied hot begins to cool rapidly, immediately after being mopped upon the surface. Although in its hot state it is capable of softening a skin coat upon the felt to which it is applied and thereby getting a grip upon the texture of the material it loses this power when even slightly cooled. It is usually in this latter condition when the new sheet is pressed upon it, hence the imperfect bond which usually results if this sheet is skin coated. But when such coating is absent the compound is given direct access to the body of the felt and a perfect bond is insured with no spots insecurely fastened as is often the case with similar material coated on two sides.

To these marked advantages of felt coated upon one side only are added still others of marked importance from a practical standpoint.

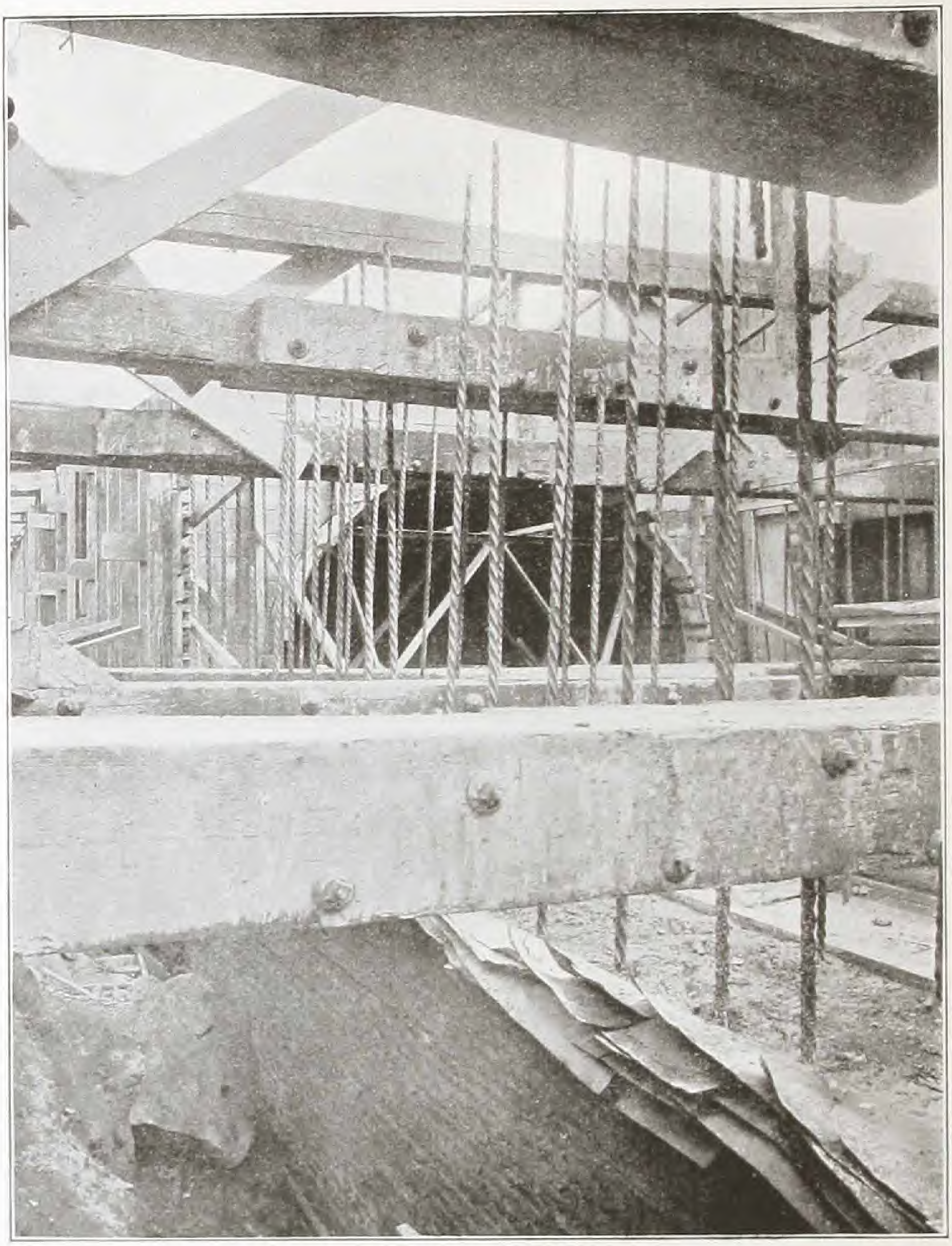
By the omission of one coat, the weight is decreased while the strength which is practically unaffected by the extra coat, remains substantially the same. In other words, a thinner, lighter and more pliable felt is secured without impairing its strength. Because of its decreased weight it is easier to handle and because of the thoroughness of the bond it insures the greatest security against dampness, for when cemented together with the certainty attendant upon the use of single-coated felt the mass consisting of several plies becomes absolutely homogeneous; an impossible barrier for water. The lightness of this felt materially facilitates its use, for work may be carried on more expeditiously and with greater certainty of satisfactory results.

Of especial advantage is this feature in the waterproofing of a vertical wall. With ordinary felt coated upon both sides the

effect of the already applied hot compound is, as already indicated, to simply soften up the skin coat of the first sheet and to a lesser degree that of the second sheet which is pressed against it. The whole mass then remains in a semi-fluid condition, for the compound used to cement the sheets together remains plastic for some time. As a result of the presence of this excess of viscous material between the sheets the second sheet has a strong tendency to slide off of the first unless it is securely held in place for some time by means of a heavy weight laid on the sheets where they are turned over the top of the wall. During this period it must be firmly pressed against the wall by an elaborate system of planks and braces.

Practically all of this annoyance is avoided and certainty of bond is assured when the felt is coated on one side only. Not only is a bond more quickly and securely made by pressing the uncoated side against the cementing compound, but the sliding motion may thus be retarded, while the lessened weight of the felt greatly reduces the pull.

The weight of a reliable wool felt before saturation should be from 5 to 7 pounds per 100 square feet. When saturated and coated one side it should weigh roughly from 12 to 14 pounds per 100 square feet, while the weight of a similar area saturated and coated on both sides should range from about 14 to over 16 pounds.



APPLICATION OF TUNALOID

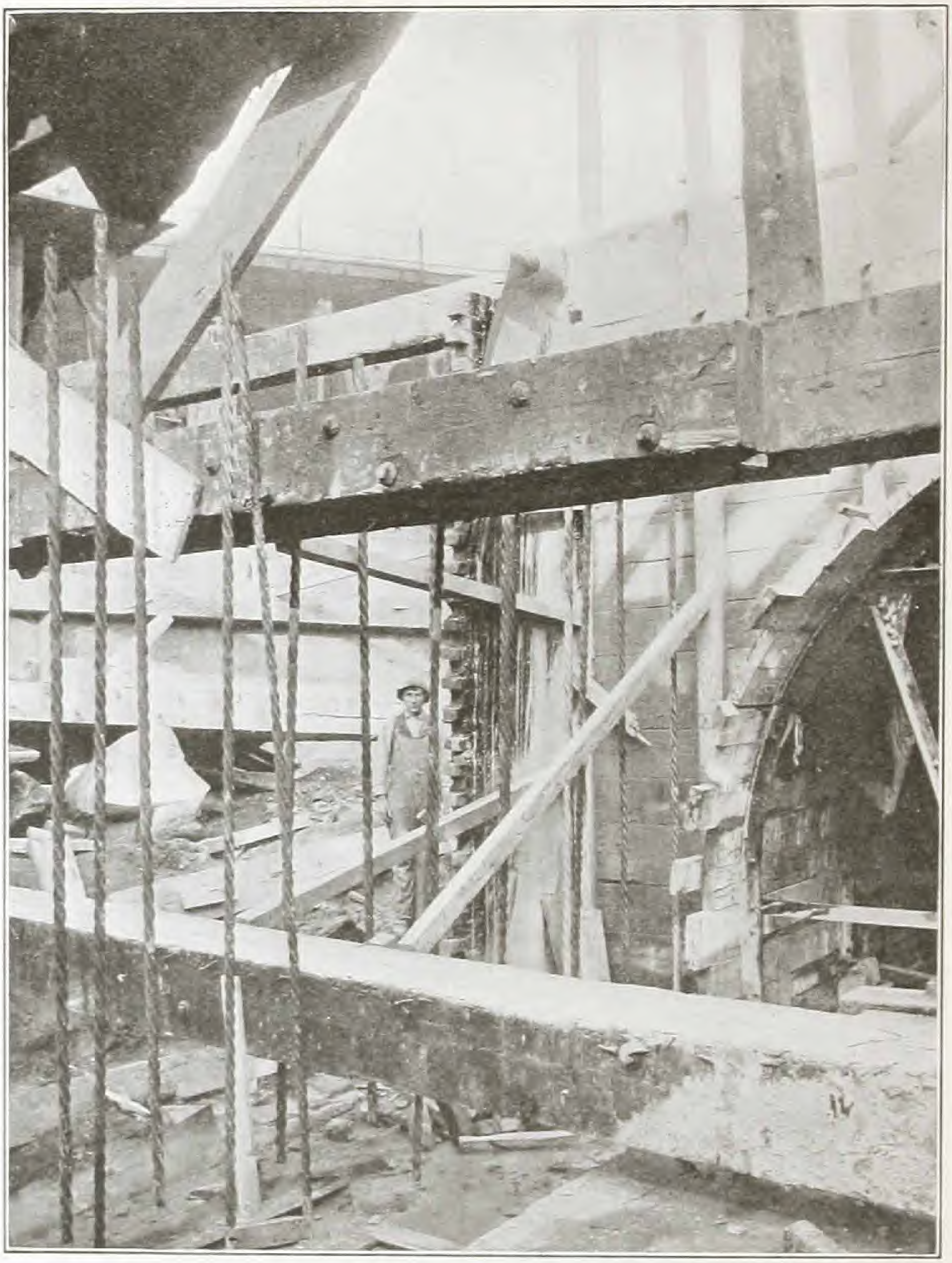
PENNSYLVANIA TUNNEL & TERMINAL RAILROAD COMPANY'S IMPROVEMENTS, NEW YORK AND SUNNYSIDE, LONG ISLAND

Tunaloid and Its Application

THIS somewhat extended but nevertheless very necessary consideration of the conditions of sub-level construction; the various methods of preventing the entrance of water and the requisites of materials to be used in the application of the envelope method cannot fail to emphasize the fact that a satisfactory waterproof felt or a suitable compound is not the creation of a day. Such materials are not brought to perfection except as the result of expert knowledge, long experiment, and thorough trial under exacting conditions.

For, generations J. A. & W. Bird & Co. have been designers and manufacturers of waterproofing materials, felts, compounds, roofing, etc. For years, experiments have been conducted to determine the efficiency and endurance of materials for the waterproofing of sub-level construction, where the entrance of water under heavy pressure must be resisted. The result is represented by "Tunaloid Waterproof Felt," "Tunaloid Compound," and "Tunaloid Damp-Proof Paint." With these three materials a complete structure may be thoroughly protected. The name "Tunaloid" was bestowed because of the primary use of the felt in connection with tunnel construction where the most difficult of all conditions were encountered and overcome. What Tunaloid has there accomplished, it may be relied upon to accomplish elsewhere under less adverse conditions.

Tunaloid Waterproof Felt is essentially a wool felt, tough and fibrous, and containing the suitable quantity of wool to secure and maintain the proper balance between strength of felt and degree of saturation. It has already been shown that too much wool is as detrimental as too little. The saturant likewise conforms to the requirements of the resistance to the effect of water or chemicals present in the soil, to enduring



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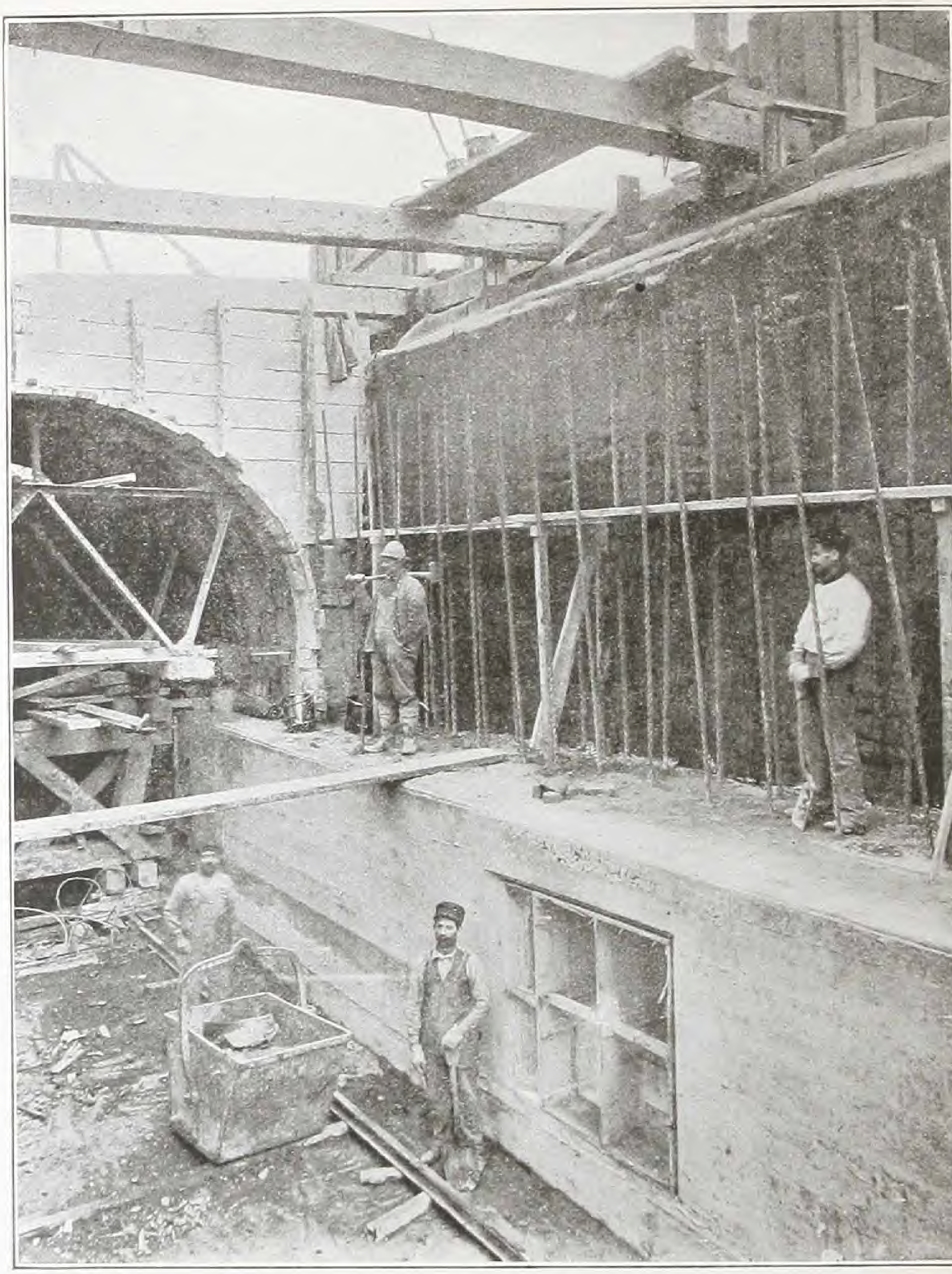
plasticity which constantly maintains the pliability of the felt, and to its easy manipulation without sticking. In fact it embodies every quality obtainable in the highest grade material.

In the manufacture of Tunaloid, the use of tar in any form as a saturant has been avoided. The saturating compound which is made up specifically for insulation against water or moisture is a combination of gums and mineral non-volatile oils, and retains some of the properties which were formerly found in coal tar, but which are now extracted from it before it is used in saturating the so-called tar felts. In fact the material ordinarily used is nothing more than a residuum having little value for any purpose. In the compound used for saturating Tunaloid the injurious chemicals have been extracted and others added so as to secure the most lasting and durable results with the very highest insulating properties obtainable. Special attention has been paid to retaining the properties which have an affinity for the good and reliable qualities of mineral pitches, and particularly of Tunaloid Compound which may be used as a cementing medium. The result of this careful selection and preparation of materials is a felt of highly superior quality which under experimental test as well as in regular practice remains uniformly waterproof. Many tests have been made upon Tunaloid which confirm this statement. Among these are those conducted at the University of Wisconsin by Professor F. M. McCullough, who makes the following report on waterproofing tests of Tunaloid and tar.

"Four 6-in. pipes, 12 in. long, were filled with 1:3:5 concrete October 25, 1909. These specimens were waterproofed November 12, 1909, in the following manner. A coat of hot tar was applied to the upper surface of the concrete; a sheet of Tunaloid was now placed on this tarred surface and carefully smoothed down with the hands. Alternate layers of tar and Tunaloid were applied in the same way until the specimens were covered with three thicknesses of Tunaloid and four layers of tar. The rough and skin coated surfaces of the Tunaloid were always placed together. On November 30



APPLICATION OF TUNALOID

PENNSYLVANIA TUNNEL & TERMINAL RAILROAD COMPANY'S IMPROVEMENTS, NEW YORK AND SUNNYSIDE, LONG ISLAND

the specimens were attached to the permeability apparatus and for the next 11 days the waterproofed surfaces of the specimens were subjected to pressures of water varying from 38 to 40 pounds per square inch. The waterproofing gave very satisfactory results as the specimens showed no flow whatever during this period."

But the distinctive feature of Tunaloid, which differentiates it from all felts, lies in the coating of one side only. The disadvantages of a felt coated upon both sides have already been presented. In Tunaloid these are avoided. Only the most minute dusting with talc is necessary to keep the adjacent surfaces (one coated and one uncoated) from sticking together when the felt is tightly rolled. As a consequence there is no resistance by the dusted surface to the ready entrance of the cementing compound when the felt is applied to the work. But of far greater importance, as the result of leaving one side uncoated, is the readiness with which this cementing compound, in its rapidly cooling condition enters into the very pores of the fabric, absolutely insuring thorough adhesion between the successive layers of felt as they are laid. Tunaloid is the thinnest waterproof felt made, but its tensile strength is equal to that of the heaviest felt.

The method of coating Tunaloid on one side only is of very great advantage to the user. Not only does it enable him to carry out his work more expeditiously, but it is an undisputable fact that a much better bond between the two sheets is secured than in the case of a waterproofing felt coated on both sides.

As the omission of the coating on one side reduces the weight of the felt, so also does it increase the facility with which it may be handled, particularly on vertical wall surfaces. The general method of application of Tunaloid Waterproof Felt and Tunaloid Compound is made clear by the accompanying illustrations and succeeding notes regarding the same:

It is always laid in several plies or layers so as to cover all parts of the surface with from two to ten thicknesses. To secure the best results it must be "shingled;" that is, each

APPLICATION OF TUNALOID

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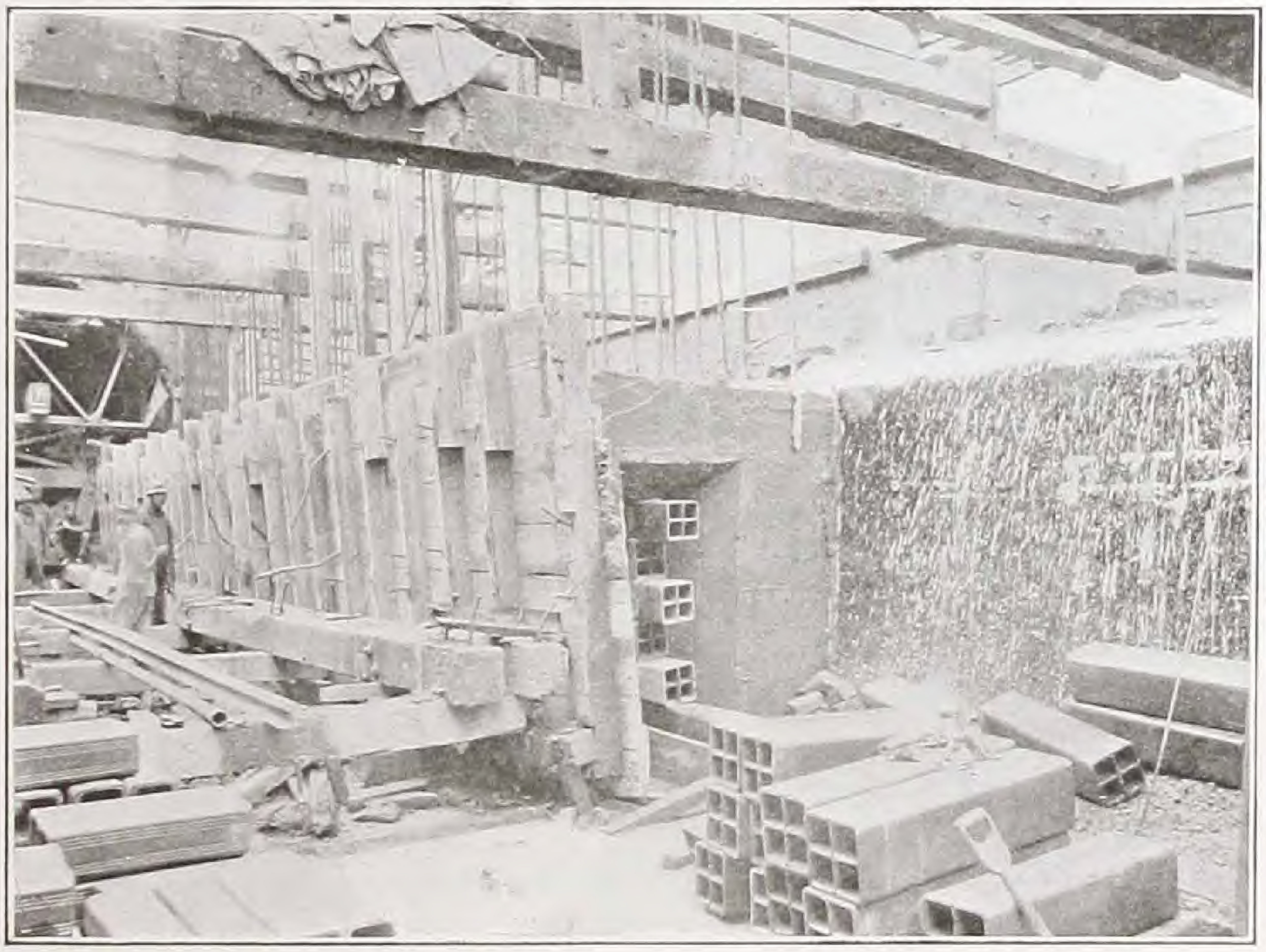
strip or width must overlay the next adjacent strip. The process may be described as follows:

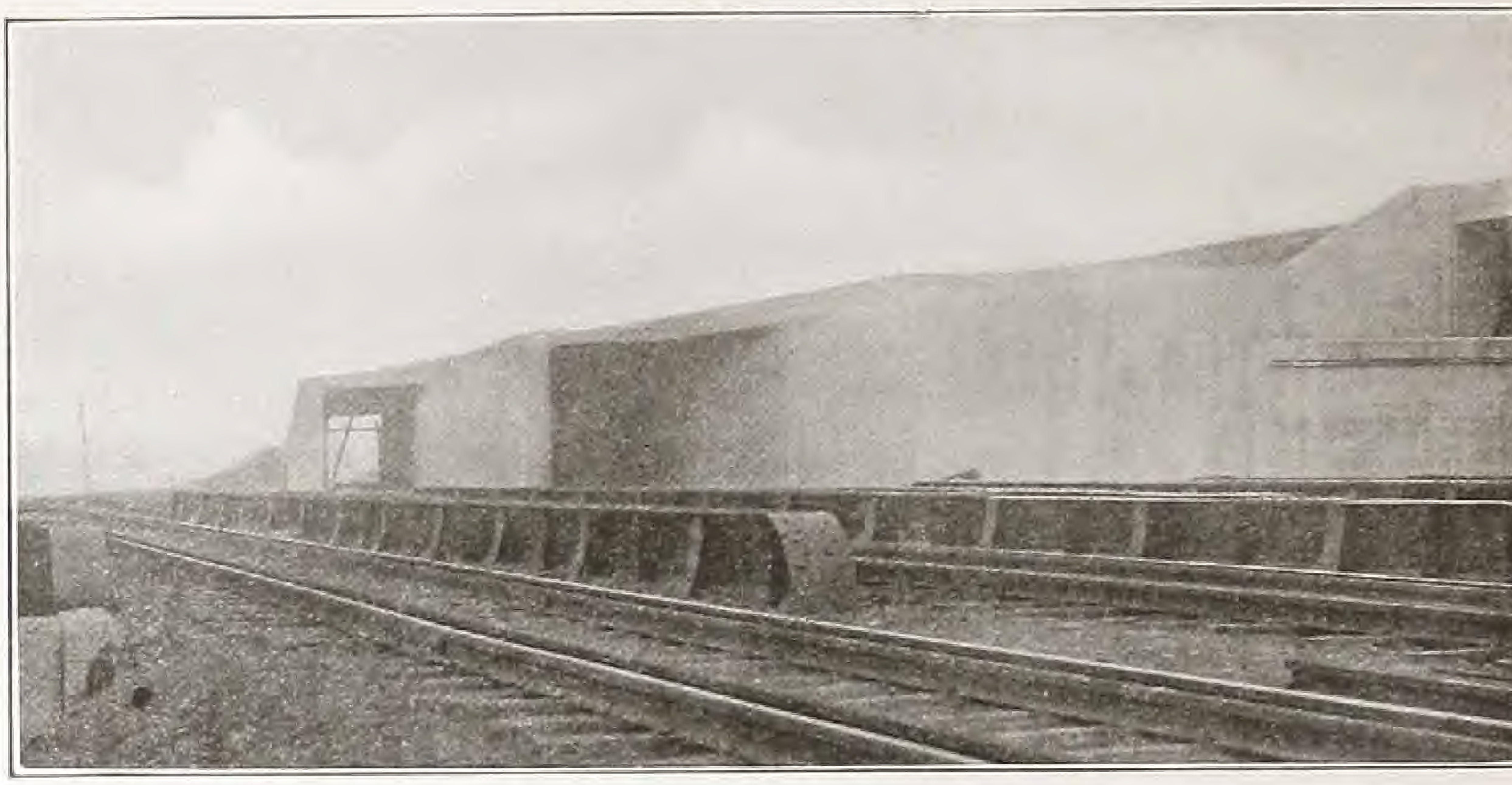
First, all of the surface to be waterproofed must be made thoroughly smooth if necessary by the application of cement mortar, and this must be allowed to become thoroughly dry before the cementing compound is applied. This compound, thoroughly heated, is applied with a mop and the felt immediately rolled over the surface. Where it is possible several rolls should be started at once and the cementing compound swabbed on the surface ahead so that there is the least possible loss of time in covering it with the felt and pressing the same into position.

The first roll having been started and mopped, the second is placed so as to overlap the first by a width, depending upon



APPLICATION OF TUNALOID

PENNSYLVANIA TUNNEL & TERMINAL RAILROAD COMPANY'S IMPROVEMENTS, NEW YORK AND SUNNYSIDE, LONG ISLAND



PENNSYLVANIA TUNNEL & TERMINAL RAILROAD COMPANY'S IMPROVEMENTS, NEW YORK AND SUNNYSIDE, LONG ISLAND

WATERPROOFED WITH TUNALOID

the number of plies to be laid. For instance, if the felt is 32 inches wide and it is to be laid 6-ply the lap of the second roll over the edge of the first will be about 26⅔ inches or five sixths of the width. As soon as the second roll has been sufficiently unrolled to allow space, the third roll is started so as to lap both of the others. This process with the corresponding mopping is continued for the entire width of the surface which is to be covered. The result is a homogeneous mass having equal thickness and strength throughout, forming an impassable barrier to water and possessing a degree of pliability which enables it to yield to distortion of the structure to which it is applied.

The numbers of layers or plies required for any given structure must depend upon the existing conditions. Specific tabulation for different depths is apt to be somewhat misleading because of the varying conditions of structure, soil, etc. For work extending but a few feet below the surface three or four plies will almost always serve to insure adequate protec-

tion, but for most work running deeper than this at least five or six plies will be required.

In the use of Tunaloid Waterproof Felt the uncoated side of the sheet is always pressed into the coating of the cementing compound. This leaves the coated side of the sheet exposed to view. The hot compound which is applied to this surface softens and combines with the coating on the felt so that it is not difficult to get a firm grip on the next sheet of which the uncoated side is pressed against the film of cementing compound. But before the second and succeeding sheets

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WATERPROOFED WITH TUNALOID

can be laid one upon another, the compound which separates them is bound to cool because of its contact with the colder surface of the under sheet or the walls of the structure. As a result the compound which has been mopped upon the surface becomes slightly glazed over. It therefore tends to resist adhesion to a somewhat similar hard coated surface on a piece

of felt, but in the case of Tunaloid this coating is lacking, and the fibrous surface of the uncoated side presents a far better opportunity for the rapidly cooling compound to take hold and bite in to the fibre. This simple difference between Tunaloid and other felts is a most vital feature in its successful use.

The instantaneous adhesion which results from this condition very much simplifies the application of felt waterproofing to a vertical wall. The fact that the uncoated surface has not been dusted with material to prevent its adhesion within the roll as is necessary with felt coated on two sides materially increases the ease with which the cementing compound penetrates the surface. As already indicated the lightness of Tunaloid felt is an important factor in the readiness of handling it upon vertical walls. In the case of heavier felts coated on both sides it is necessary to provide sufficient means to prevent their sliding

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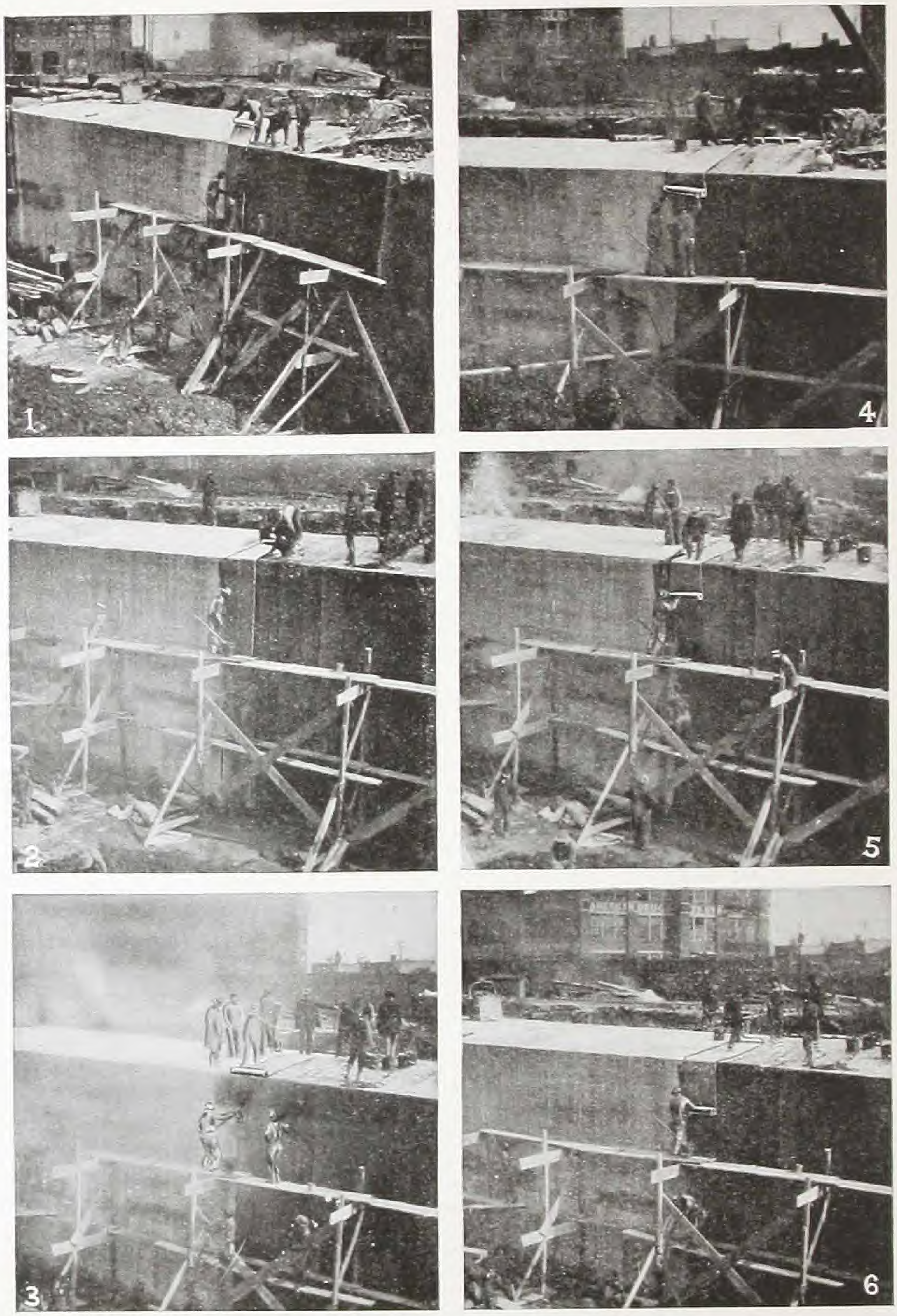
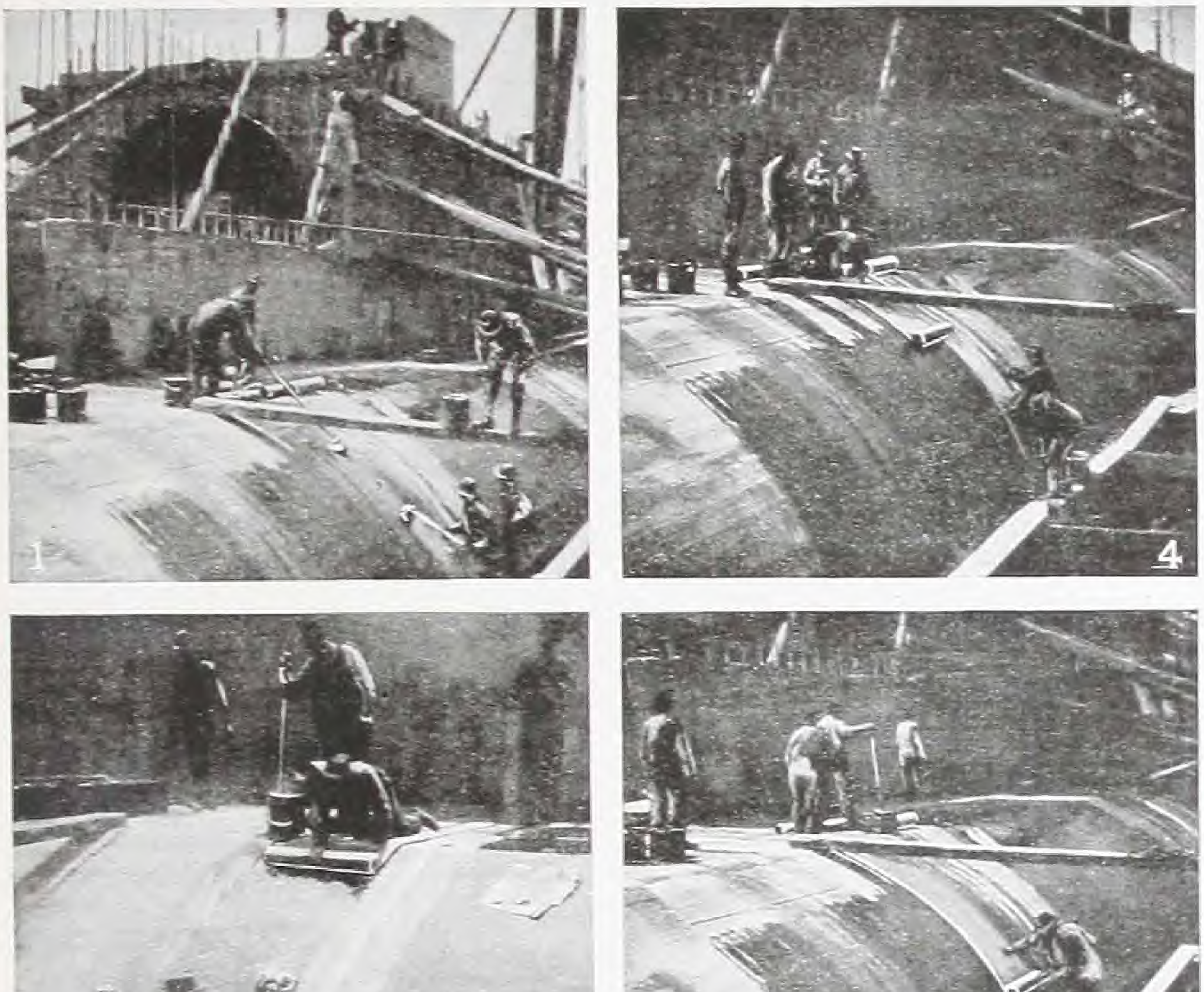
off when first applied. This naturally results from laying two skin coated surfaces of felt together with a viscous substance like the cementing compound between them, but when the uncoated side of a sheet of Tunaloid is applied to the coated side of the preceding sheet of the same material which has been treated with a hot compound, the two sheets become thoroughly amalgamated and the outer sheet is readily supported by adhesion. In fact the Tunaloid method provides sufficient and only sufficient binding material to securely and permanently hold the two sheets together.

Experience shows that a hot cementing compound takes hold better and penetrates further than one that is applied cold; as a result, a better bond between the sheets is secured. Conditions must determine the exact character of the compound. Broadly speaking, a satisfactory compound should soften at ordinary atmospheric temperatures and melt at about 100 degrees F. It should contain such a proportion of oils as may be essential to giving it elasticity and long life. So far as possible it should stand great extremes of temperature and should retain its cementing qualities under all conditions, not becoming hard and brittle at low temperature, or too fluid at high temperature. These characteristics distinguish Tunaloid Compound which has been carefully developed by experiment to serve as the most suitable material for cementing together the sheets of Tunaloid Waterproof Felt.

Most of the accompanying illustrations clearly indicate without further explanation the location and in general the method of application of Tunaloid Waterproofing Felt. The selection of photographs of actual work has been intentionally restricted with a few exceptions to those taken upon a single large undertaking, namely, the improvements made by the Pennsylvania Tunnel & Terminal Railroad Co., at New York and Sunnyside, Long Island. This covers a wide diversity of construction both underground and overhead. This work alone required the use of over 9,000,000 square feet of Tunaloid Waterproof Felt.



APPLICATION OF TUNALOID TO THE EXTERIOR OF A CONCRETE TUNNEL WITH VERTICAL WALLS



APPLICATION OF TUNALOID TO THE EXTERIOR OF AN ARCHED CONCRETE TUNNEL

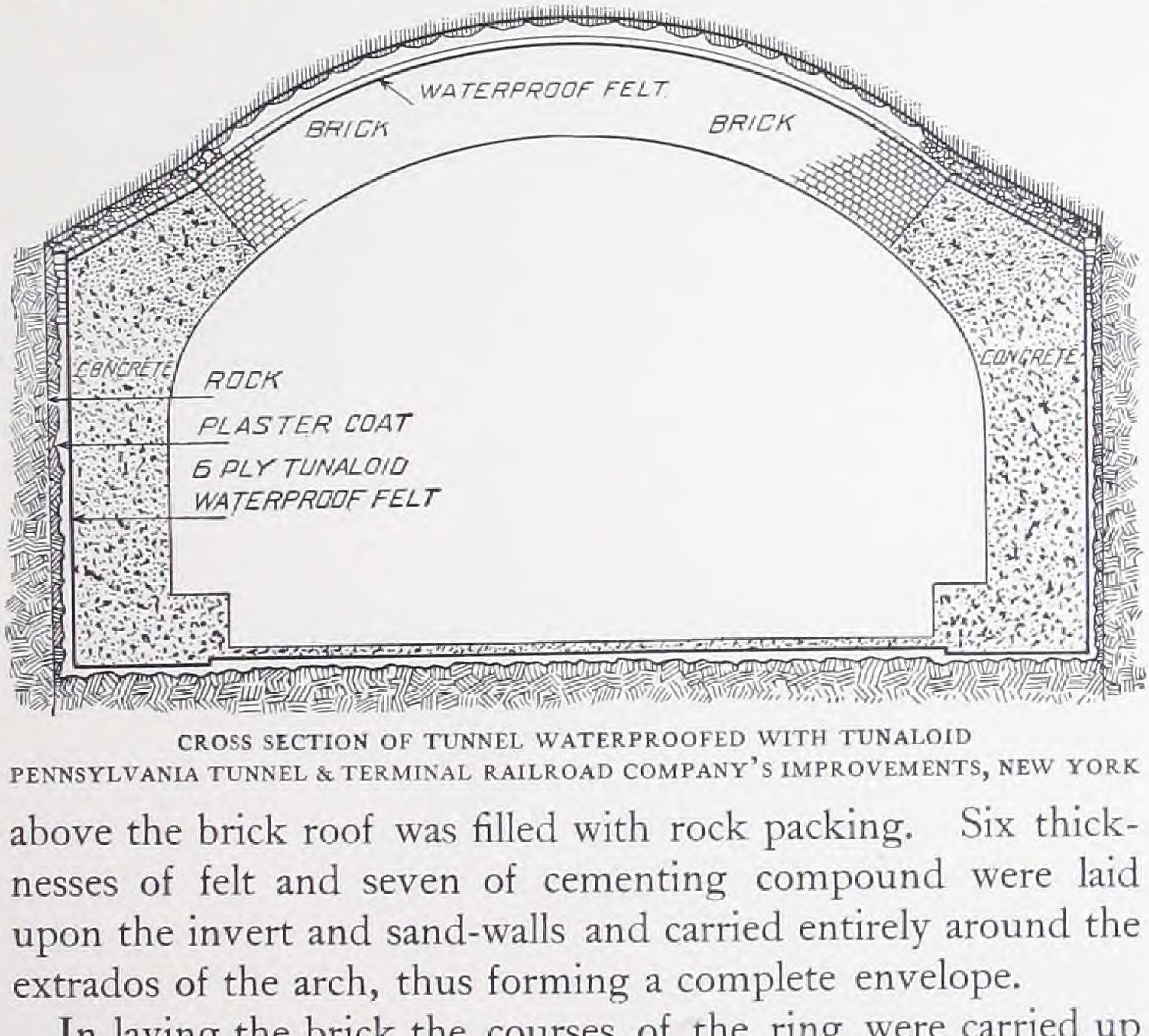
The groups of successive photographs shown upon the two preceding pages make quite clear the method of applying Tunaloid on the tunnels which form a large proportion of the construction in connection with the previously mentioned improvements. In both cases the surfaces to be waterproofed were exposed and easily accessible. All construction was of concrete and all waterproofing felt was protected by an exterior or armor course of brick or cement. By following through these illustrations in the order of their numbers the progressive steps in the application of Tunaloid may be made clear.

In case of the tunnel with vertical walls the free end of a roll of felt was lowered to the ground with the uncoated surface of the felt next to the wall which had already been thoroughly mopped with cementing compound. The roll itself was held from above and the felt at once securely pressed against the vertical wall. The practically horizontal top of the tunnel was then mopped and the felt unrolled toward the other side, as shown in the second cut. In the succeeding cuts the roll is shown as being still further unrolled on the other vertical side until it finally reaches the ground and is pressed against the surface which has been mopped in advance of its descent. This felt was all laid 6-ply.

As the work progressed, the waterproofing on the top of the tunnel was permanently protected by a single course of brick, or in some cases by a somewhat less thickness of concrete. The waterproofing upon the sides was protected by a single thickness wall of brick extending to the top.

In the case of the arched concrete tunnel the felt in successive rolls was started from the top and unrolled over the freshly mopped surface until it reached ground level. Other rolls followed in succession so as to secure a homogeneous 6-ply envelope or shield with suitable laps. In all cases the rolls were started with the uncoated sides toward the concrete so that the outer surface of the finished envelope presented the coated side of the felt, which was given a final mopping. All of this work was protected by one course of brick laid over the arch.

The accompanying cross sectional drawings of single and twin-tunnels clearly indicate the methods employed for waterproofing with Tunaloid some of the sublevel work which formed a part of the improvements undertaken in New York City by the Pennsylvania Tunnel & Terminal Railroad Co. The single arch type here shown with a heavy brick arch, was constructed in tunnel; in the open cut sections the roof was of concrete. Both were completely waterproofed with Tunaloid on the invert, roof and sides; in the tunnel sections the space

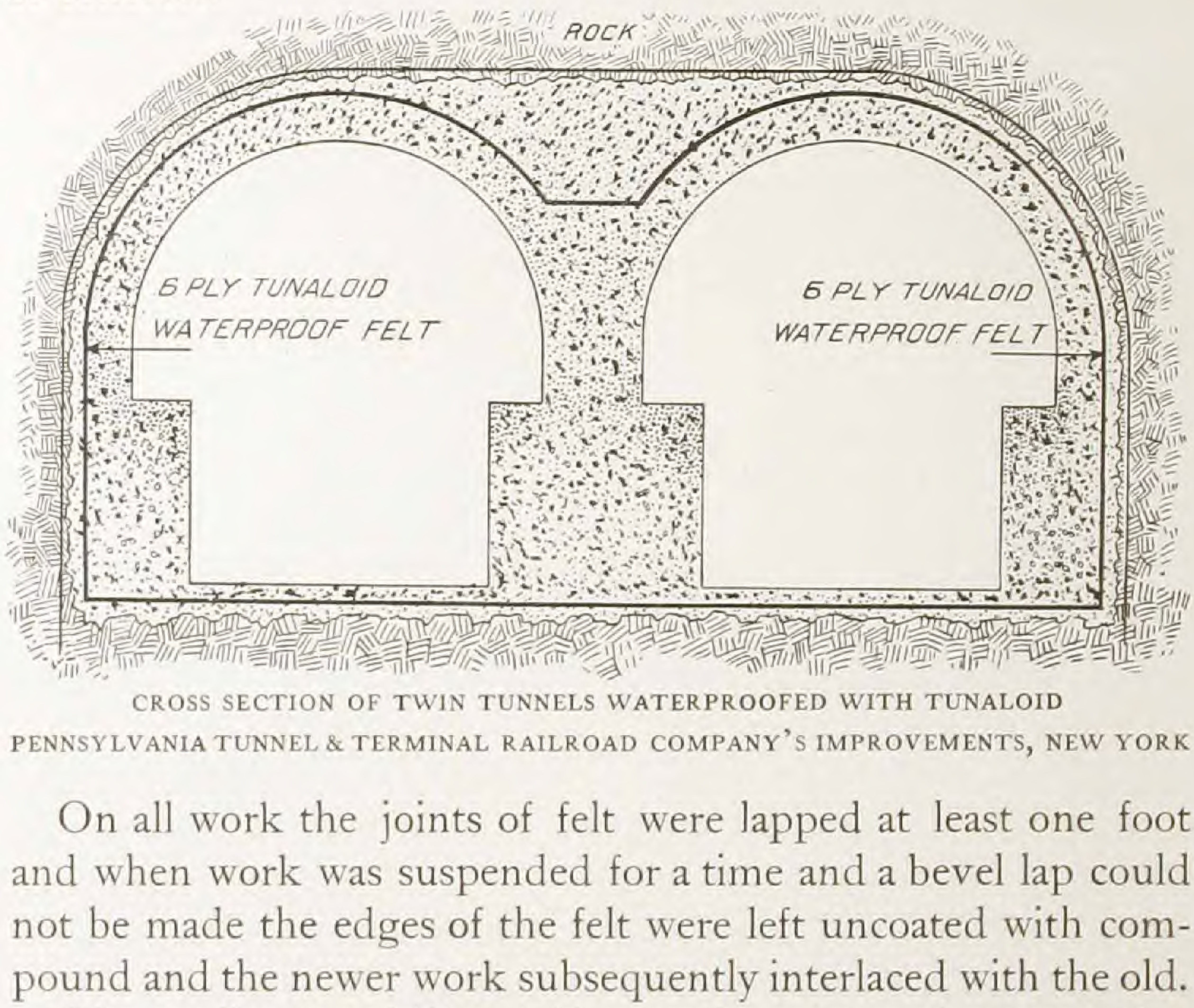


CROSS SECTION OF TUNNEL WATERPROOFED WITH TUNALOID
PENNSYLVANIA TUNNEL & TERMINAL RAILROAD COMPANY'S IMPROVEMENTS, NEW YORK

above the brick roof was filled with rock packing. Six thicknesses of felt and seven of cementing compound were laid upon the invert and sand-walls and carried entirely around the extrados of the arch, thus forming a complete envelope.

In laying the brick the courses of the ring were carried up as high as the void between the extrados and the rock would permit and still leave a working space in which to place the waterproofing. This was laid for that height, joined to the previous waterproofing on the side walls and followed by the brick armor course over the waterproofing and finally by the rock packing.

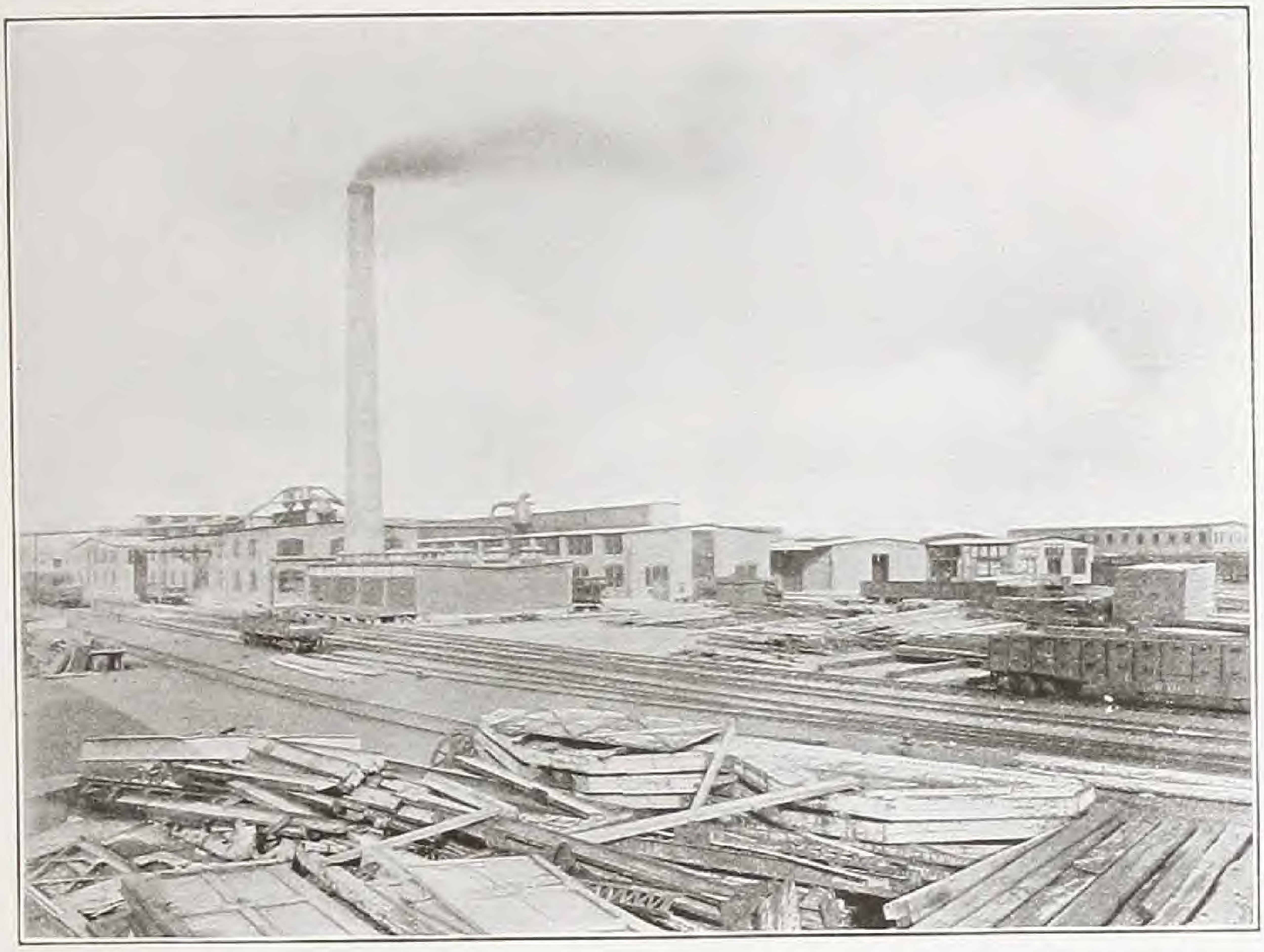
The plans originally contemplated the use of a complete concrete lining in the twin-tunnels except where large quantities of water were encountered, in which cases the arches, beginning at about 15 degrees above the springing line, were to be built of vitrified brick. The waterproofing was then carried completely over the arch. In the construction of twin tunnels entirely of concrete the waterproofing was similarly carried up the sand walls and then over the extrados as fast as the concrete was laid and then protected by an armor course of concrete.



CROSS SECTION OF TWIN TUNNELS WATERPROOFED WITH TUNALOID
PENNSYLVANIA TUNNEL & TERMINAL RAILROAD COMPANY'S IMPROVEMENTS, NEW YORK

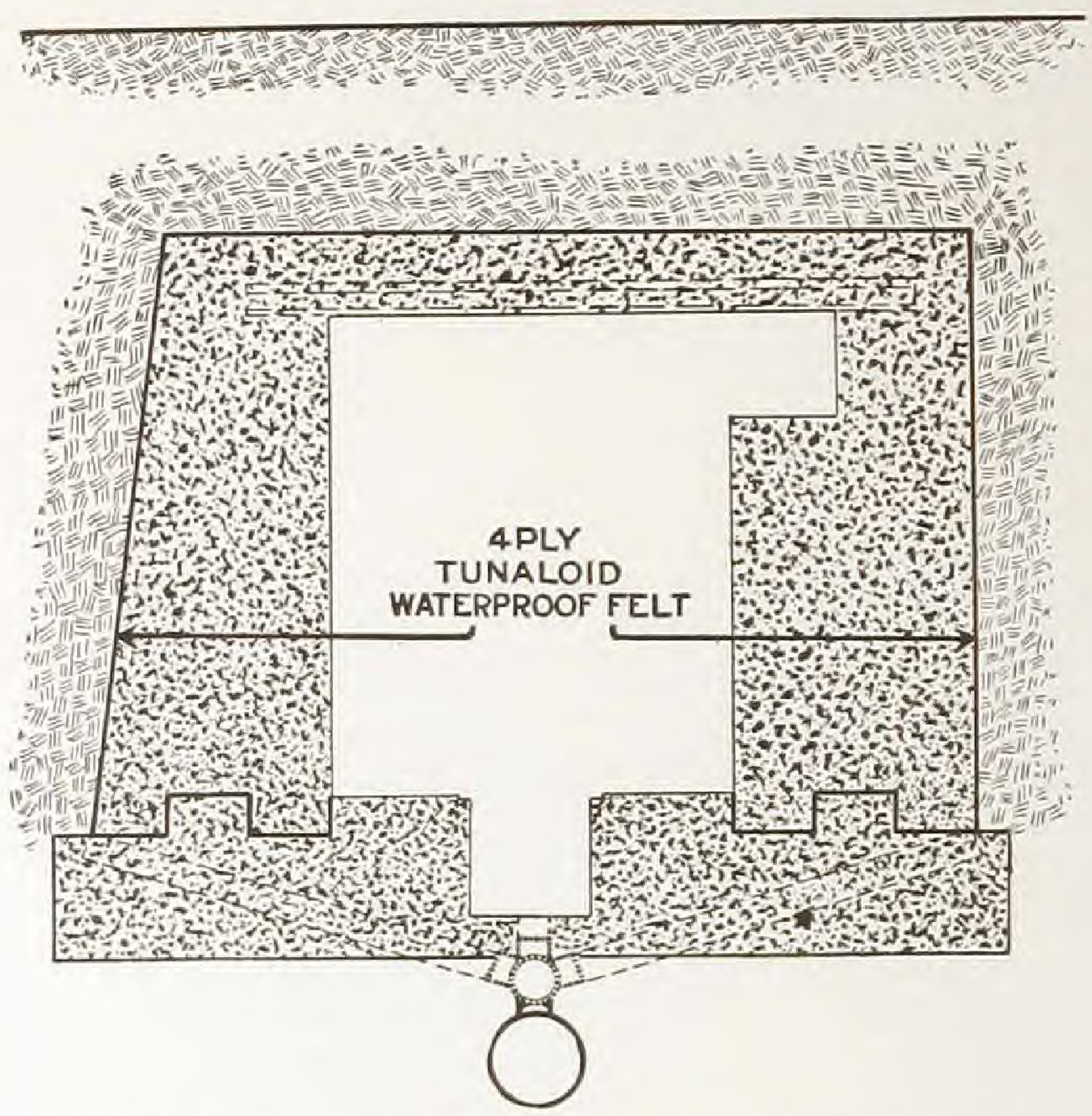
On all work the joints of felt were lapped at least one foot and when work was suspended for a time and a bevel lap could not be made the edges of the felt were left uncoated with compound and the newer work subsequently interlaced with the old.

The application of Tunaloid to various types of construction at the Sunnyside improvements is so comprehensively shown by the preceding photographs that no particular description of methods appears to be necessary. Practically all of the work was done in open cut or well above ground level and was therefore lacking in most of the difficulties of the construction just described.

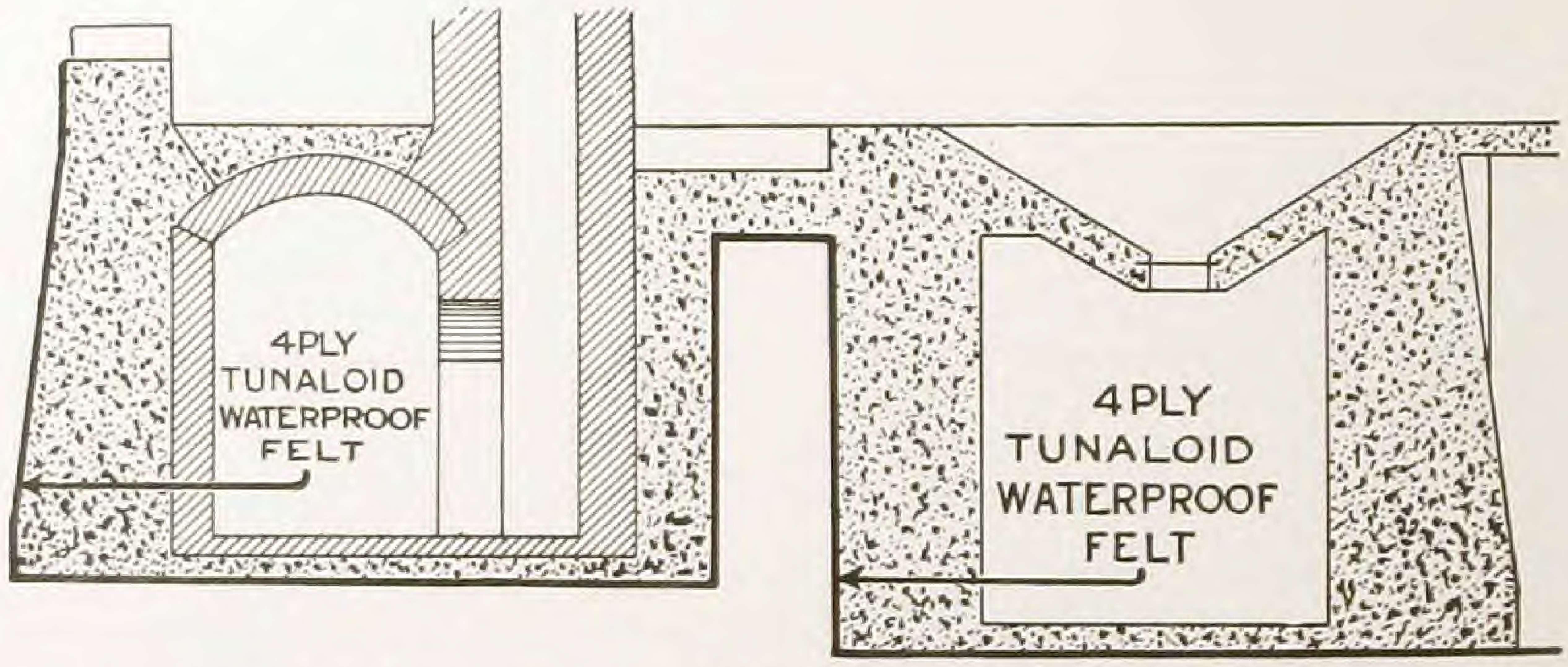


KINGSLAND CAR SHOPS, DELAWARE, LACKAWANNA & WESTERN RAILROAD, KINGSLAND, N. J.

The following illustrations of waterproofing with Tunaloid done in connection with sublevel work at the Kingsland car shops of the Delaware, Lackawanna & Western Railroad, at Kingsland, N. J., show very clearly the manner of treating such work. In connection with the power plant at these shops there was planned an extended system of relatively small tunnels for steam pipes, electric wires, etc. These were located only just below ground level, and were somewhat complicated in form, as is evident from the accompanying illustrations. They were all made of concrete, the Tunaloid waterproof felt covering the tops and sides of those extending between buildings. Drains were laid beneath these tunnels so that thorough drainage of the surrounding soil was insured and opportunity provided for the escape of any water which might collect within the tunnel. For this reason it was not necessary to waterproof its bottom in the case of tunnels in the open yard.

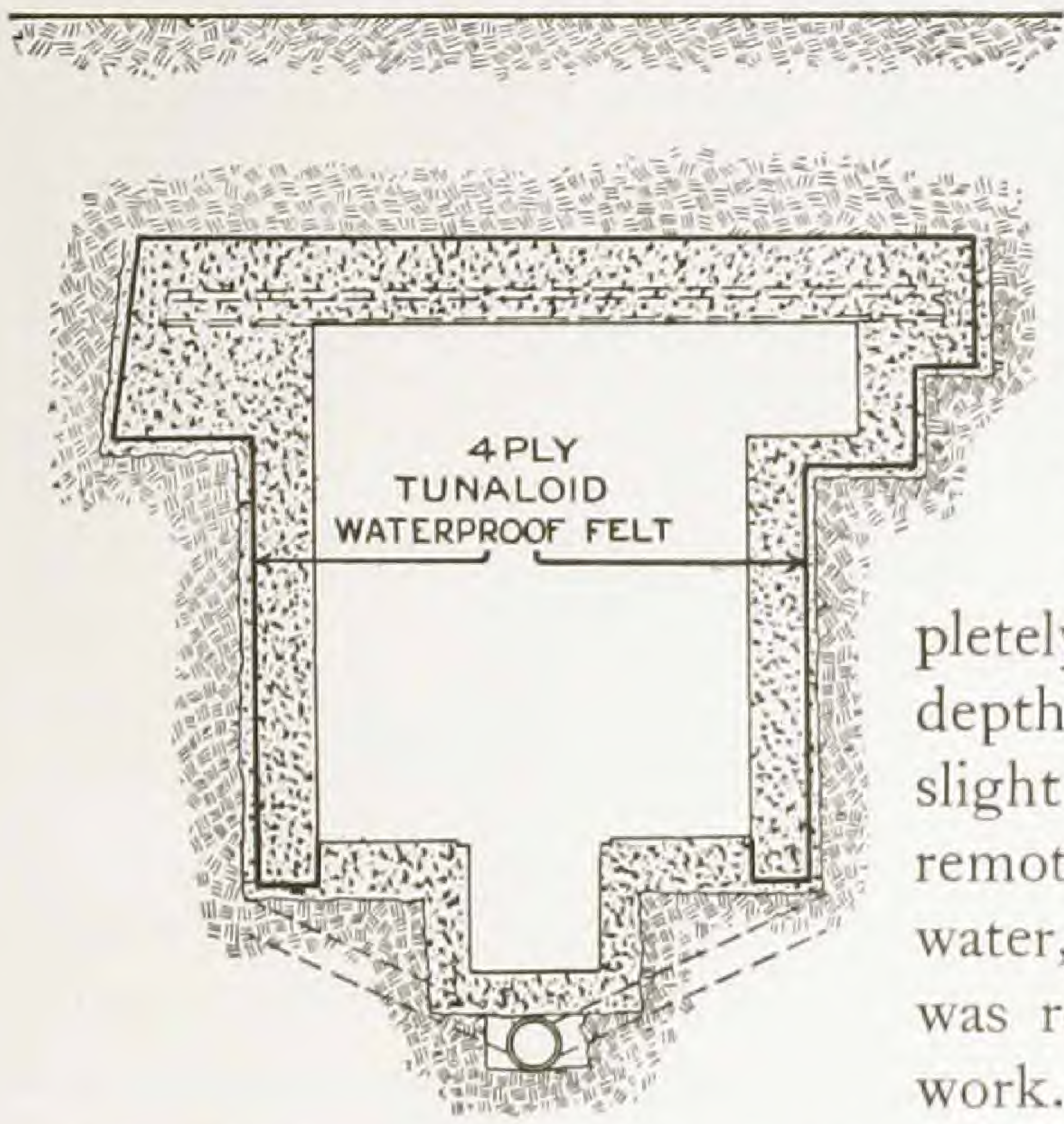


APPLICATION OF TUNALOID TO STEAM PIPE AND ELECTRIC WIRE SUBWAY



APPLICATION OF TUNALOID TO ASH TUNNEL AND STEAM PIPE AND ELECTRIC WIRE SUBWAY.

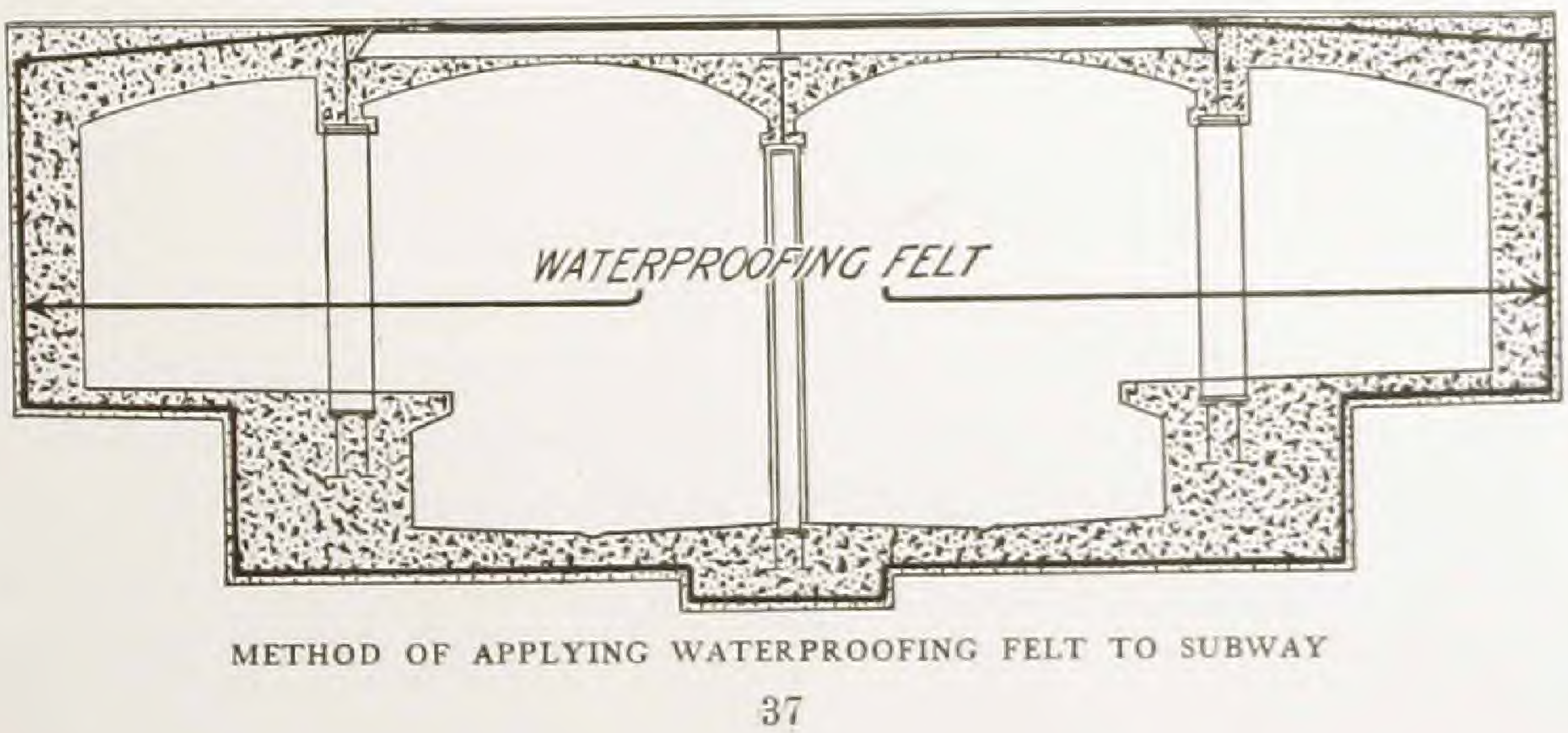
SUBWAY CONSTRUCTION, KINGSLAND CAR SHOPS, DELAWARE, LACKAWANNA & WESTERN RAILROAD, KINGSLAND, N. J.



APPLICATION OF TUNALOID TO SUBWAY
D., L. & W. R. R.

But in the case of the parallel ash and steam tunnels beneath the power house felt was carried entirely beneath, and the walls of the concrete construction thus completely enveloping it. The depth being comparatively slight and the opportunity remote for the pocketing of water, only 4-ply of Tunaloid was required on any of this work.

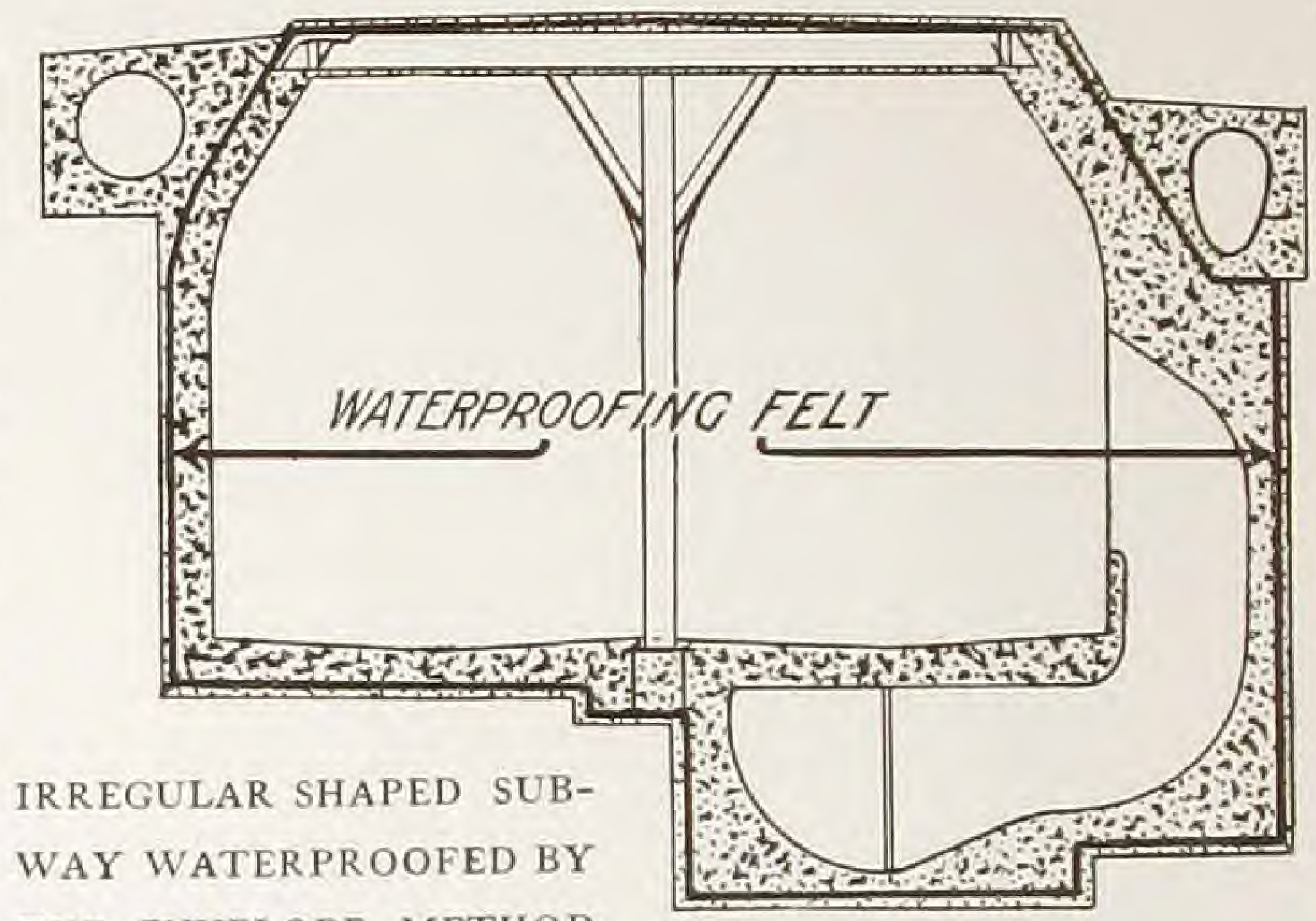
The universal applicability of the envelope method of waterproofing can hardly be better indicated than by the accompanying cross sections of more or less irregular subway construction. In each case the felt completely surrounds the concrete structure. When the difficulties encountered in building a subway in the congested streets of a city are considered, it must be manifest that the envelope or exterior method would not be employed, in place of applications to the inner walls unless it was deemed



METHOD OF APPLYING WATERPROOFING FELT TO SUBWAY

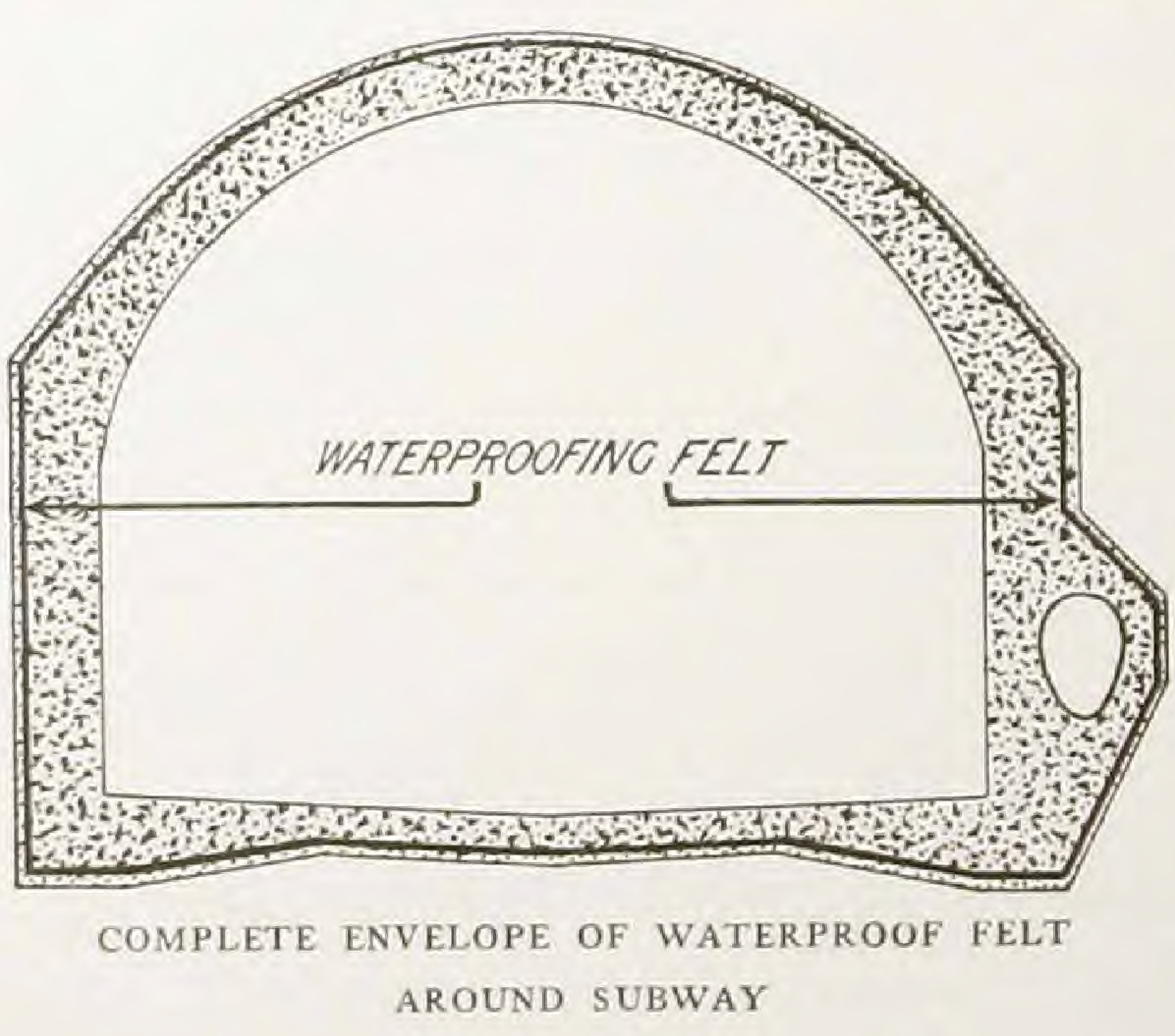
far more reliable.

The manner of applying the felt and carrying it up over the top of the subway must of necessity be influenced by the conditions of construction, for seldom is it possible to make a clear cut and build up the work as a unit.



IRREGULAR SHAPED SUBWAY WATERPROOFED BY THE ENVELOPE METHOD

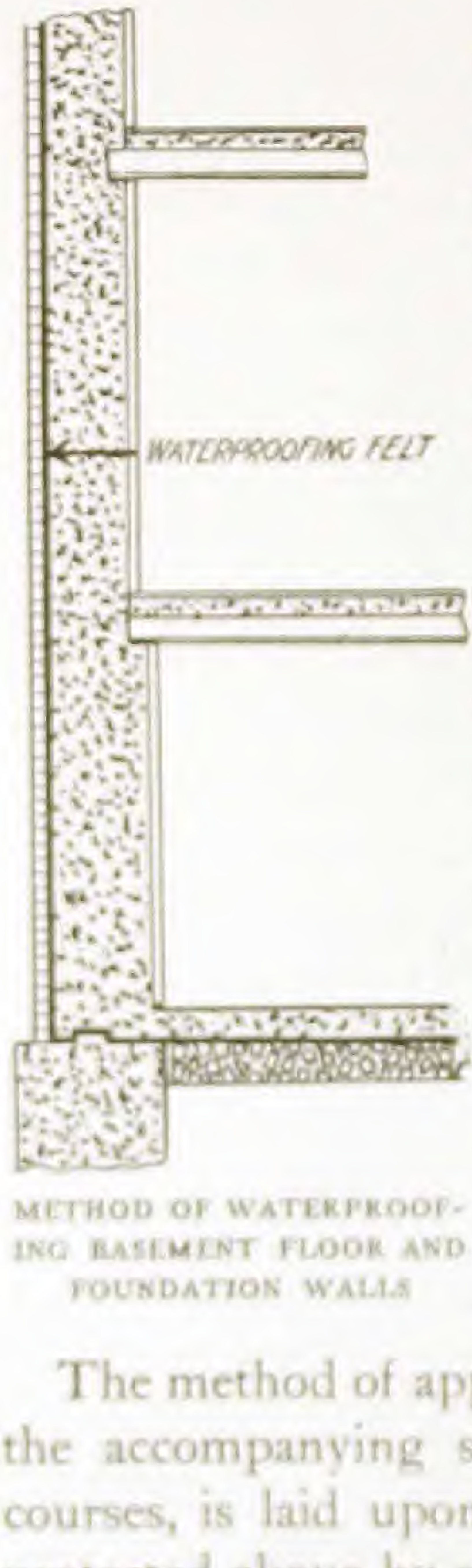
If it is done piecemeal so also must be the waterproofing, but the interlacing of thicknesses of felt simplifies the joining of new work to old. No general method of construction can be established for such work, for variations must be made even after all plans are completed to meet unexpected conditions. The street may be excavated only enough to allow the roof beams to be set in position from side wall to side wall and the roof finished first. The core may then be excavated underneath. Or the side walls may be entirely completed before the floor or invert is laid. Shoring of adjacent building walls may be necessary or the new tunnel may displace an old sewer. In such case it may be necessary to first build the side walls containing new sewers into which the sewage must first be turned. Nevertheless the entire structure may be successfully enveloped in multiple layers of felt and the admission of water effectually prevented.



COMPLETE ENVELOPE OF WATERPROOF FELT AROUND SUBWAY

If waterproofing is necessary in such comparatively rough underground structures as have already been described, manifestly it is imperative in the case of a building with fine interior finish. It is not the purpose here to either illustrate or describe in detail the various applications of Tunaloid Waterproof Felt to foundation walls. It is merely sufficient to point out the general features of the method. Of course the simplest application is in the case of walls, the outside of which are exposed, and to which the felt may be readily applied. But such conditions are comparatively rare, for their very existence suggests that waterproofing is not required.

But where excavation is deep and access cannot be had to the outside of the walls after they are built, the envelope is readily formed of felt prior to the construction of the foundation. As this envelope should always be protected from damage on the outside, two purposes are served when a thin wall of brick or concrete is laid up just inside of the excavation. If this is in earth which is held back by sheeting, the problem is easily solved. If, on the other hand, the excavation is in rock the preparation of a smooth surface will depend upon the irregularity of the rock surface. To this finished surface the felt is applied in the requisite number of layers with alternate coatings, and the lower end is turned in toward the building so that the foundation rests upon it. To give double assurance of tightness the intersection of vertical wall and footings may be tongued and grooved lengthwise of the wall and the felt carried over the projection thus formed. From the wall it may be extended inward so as to protect the entire basement floor if so desired. Frequently the opportunity for drainage is such that there may be no upward effort of the water to gain entrance through the floor. But where the basement is below water level, provision for thorough waterproofing must be made by carrying the felt as an envelope underneath the entire upper course of the floor, which may be of brick or concrete, or a combination of both. The general method of applying waterproof felt to a foundation wall and basement floor is typically illustrated herewith.



METHOD OF WATERPROOFING BASEMENT FLOOR AND FOUNDATION WALLS

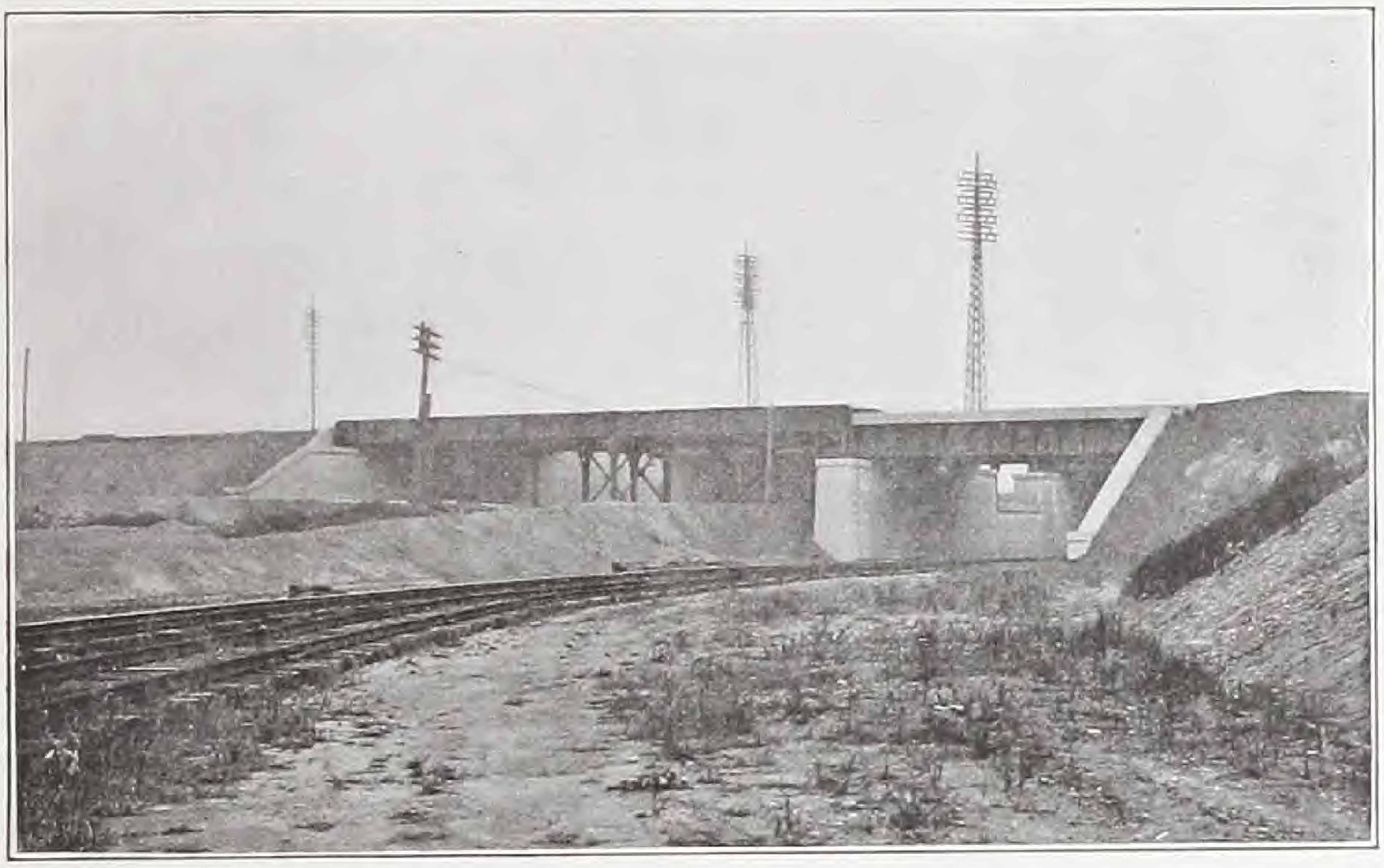
The purpose of waterproofing the basement floor is obviously to prevent water coming up through it, but it may be desired to waterproof the upper floors so as to prevent water coming down through them in case of fire or leakage. The same methods of application of Tunaloid which have been described elsewhere may be employed here with assurance of permanent tightness.

In the waterproofing of all such structures especial care and critical supervision must be exercised to avoid accidental or intentional puncturing of the envelope. This is most liable to occur through the acts of irresponsible workmen who may be charged with placing of pipes and wires. The openings which are thus made, either through necessity or accident, must be carefully repaired by those who are competent.

The method of applying Tunaloid to a bridge is indicated by the accompanying sections. This felt, usually in about six courses, is laid upon the reinforced concrete of the arch and protected above by a course of brick or cement. Upon this the ballast is filled, in which the ties are laid. Proper drainage is provided by pitching the upper surface of the concrete and attached waterproofing toward drainage holes located at regular longitudinal intervals. Absolute protection is furnished

METHOD OF WATERPROOFING A RAILROAD BRIDGE

to the concrete, seepage is prevented and the come and go due to extremes of temperature is provided for by the pliability of the felt.



LAUREL HILL BRIDGE, PENNSYLVANIA & TERMINAL RAILROAD IMPROVEMENTS, SUNNYSIDE, LONG ISLAND. WATERPROOFED BENEATH TRACKS WITH 6-PLY TUNALOID

Manifestly Tunaloid finds a place for usefulness wherever water is to be prevented from passing. But the illustrations and descriptions already presented are undoubtedly sufficient to indicate in a general way the method to be employed in any case. But waterproofing of this character may be just as essential as the means of keeping water within a structure as keeping it out. Thus Tunaloid is employed for rendering impervious cisterns, tanks and pumping chambers.

The increasing recognition of the effect of moisture upon the steel reinforcement embedded in concrete is attracting attention to the necessity of thoroughly waterproofing all such portions of a structure as may be exposed to water. Of still greater importance is the waterproofing of structural steel which is not protected by concrete, but exposed to water. This is readily accomplished by the envelope method.

Tunaloid Damp-Proof Paint

IT has been made evident that wherever external water exists, as is usually the case in connection with sublevel work, the envelope or shield method is essential and that Tunaloid Waterproof Felt is an unexcelled material for forming the envelope. But where the depth below the surface is slight and the soil is comparatively dry, or where the superstructure or the interior walls are to be protected against the normal passage of moisture, such material or method is not ordinarily necessary, and the requirements may be met by a properly compounded paint. Such is Tunaloid Damp-Proof Paint which has been "designed" so to speak, to meet the exacting requirements. Partaking of some of the characteristics of the saturant in Tunaloid Waterproof Felt and of Tunaloid Compound, this paint combines all of the qualities essential to the protection of masonry surfaces exposed to moisture.

Tunaloid Damp-Proof Paint is a thick black liquid compound from selected gums melted into a uniform mass and without pores.

When applied, it forms an elastic film over brick, concrete or similar surfaces, thereby closing the pores and excluding moisture or dampness from striking through. It is elastic under all and any conditions and of a tacky consistency.

The more or less porous condition of concrete, mortar, brick or terra-cotta, or similar materials, presents an opportunity for the absorption of paint applied to their surface, rendering difficult successful covering with a waterproof film.

What is more, the chemical action of the lime and other ingredients of cement is such that all ordinary paints are affected and often disintegrate. To offset these difficulties and prepare a compound that will successfully protect and endure without excessive waste of material is manifestly no easy task.

Tunaloid Damp-Proof Paint is an evenly flowing liquid which can be readily applied with a brush. In each case all loose dirt, shavings or foreign substance should be removed from the surface to be painted. All joints should be thoroughly and carefully pointed up and no open spaces or cracks should be left between the bricks.

On smooth surfaces where there are no deep pores, one coat will as a rule be sufficient (unless the conditions are very severe). In the case with rough brick or rough concrete, two coats should be applied, the first coat being well slapped into the pores with a brush, so that every minute hole in the surface will be thoroughly filled with the damp-proof paint.

On foundations, where the dampness is quite excessive, we recommend applying Tunaloid Damp-Proof Paint to the outside wall.

On work above ground or in a basement, where the dampness is not excessive, the inside of the exposed wall may be painted with one or two coats, no part of the wall being left untreated. The surface should be gone over carefully and retouched where necessary, in order that the coating shall be uniform. Paint between beams and window-casings, and openings at window-casings should be filled.

One or two coats of Tunaloid Damp-Proof Paint will be required according to the character of the walls and their location.

A complete unbroken film must entirely coat the surface to be covered, and this requirement is essential to success.

Water and dampness will find their way through the smallest pin-holes. Therefore, a thorough coating is required.

Note Carefully:—A wall that is full of dampness should never be painted on the outside and inside as well, as in that case the dampness is confined in the wall, with no means to escape, and will always dry out towards the heat, thus forcing off *any* paint which may be applied to that side. An opportunity for the dampness to dry out from a saturated wall must always be given.